PB-217 784

TRACE METALS IN WATERS OF THE UNITED STATES

John F. Kopp, et al

Federal Water Pollution Control Administration
Cincinnati, Ohio

30 September 1967

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TRACE METALS IN WATERS OF THE UNITED STATES

A FIVE YEAR SUMMARY OF TRACE METALS IN RIVERS AND LAKES OF THE UNITED STATES

(OCT. 1, 1962-SEPT. 30, 1967)

JOHN F. KOPP
ROBERT C. KRONER

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Federal Water Pollution Control Administration
Division of Pollution Surveillance
Cincinnati, Ohio

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TRACE METALS

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A five-year summary of trace metals
in rivers and lakes of the United States
(October 1, 1962–September 30, 1967)

U. S. Department of the Interior
Federal Water Pollution Control Administration
Division of Pollution Surveillance
1014 Broadway
Cincinnati, Ohio 45202

I

RELATED PUBLICATIONS:

National Water Quality Network
Annual Compilation of Data, October 1, 1957–September 30, 1958
Public Health Service Publication No. 663 (1958 Edition)

National Water Quality Network
Statistical Summary of Selected Data, October 1, 1957–September 30, 1958
Public Health Service Publication No. 663–Supplement I

National Water Quality Network
Annual Compilation of Data, October 1, 1958–September 30, 1959
Public Health Service Publication No. 663 (1959 Edition)

National Water Quality Network
Annual Compilation of Data, October 1, 1959–September 30, 1960
Public Health Service Publication No. 663 (1960 Edition)

National Water Quality Network
Plankton Population Dynamics, July 1, 1959–June 30, 1961
Public Health Service Publication No. 663–Supplement 2

National Water Quality Network
Annual Compilation of Data, October 1, 1960–September 30, 1961
Public Health Service Publication No. 663 (1961 Edition)

National Water Quality Network
Annual Compilation of Data, October 1, 1961–September 30, 1962
Public Health Service Publication No. 663 (1962 Edition)

Water Pollution Surveillance System
Annual Compilation of Data, October 1, 1962–September 30, 1963
Public Health Service Publication No. 663 (Revised 1963 Edition)

Storage and Retrieval of Data For Water Quality Control, Green, Richard S.
PHS Publication 1263. GPO. Washington, D.C., June 1964

Trace Elements in Six Water Systems of the United States,
Kroner, R. C. and Kopp, J. F.
A.W.W.A. 57, 150(1965)

FOREWORD

Six annual compilations of data from the Federal Water Pollution Control Administration's water quality surveillance program have already been published. This report summarizes the trace element data collected in the five-year period October 1, 1962 through September 30, 1967. The total body of these data includes approximately 30,000 separate determinations. Only one year of those data has been included in a previous publication.

The FWPCA gratefully acknowledges the assistance to its surveillance program of the participating local, State and Federal Government agencies and private industry in performing most of the conventional chemical analyses and in collecting samples for the newer, more complex examinations. The success of this program depends, in large measure, upon their continued interest and participation.

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THE FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
WATER QUALITY SURVEILLANCE PROGRAM

Introduction

The Federal Water Pollution Control Administration's Water Quality Surveillance Program has as its primary responsibility the collection, evaluation and dissemination of both water pollution control information and water quality data. The Federal Water Pollution Control Act of 1956 (PL 84-660) provides the basic authority for the comprehensive federal program to prevent and control water pollution. The amendments of 1961 (PL 87-88), the Water Quality Act of 1965 (PL 89-234), and the Clean Water Restoration Act of 1966 (PL 89-753) gave legislative reinforcement to this data collection and surveillance activity.

To fulfill this responsibility, the FWPCA's Water Quality Surveillance Program collects, interprets and disseminates:

a. Information on changes in water quality at key points in river systems, as it relates to the implementation of water quality standards.

b. Basic data on chemical, physical and biological water quality which may be used to establish water quality baselines and determine trends.

c. Data which are useful in the development and operation of comprehensive water resource management programs.

Adequate water quality surveillance is essential in order to quickly identify compliance with water quality standards, to document violations for corrective actions and to identify new pollution trends, sources and types before problems develop.

Once the Federal law had established the need for water quality data, it became necessary to determine the precise water quality measurements required. The frequency of sampling also had to be defined as well as the location of the sampling points. In general, these sampling points are in the vicinity of:

a. people and/or animal concentrations;

b. industrial activity including agricultural and heat emission sources;

c. recreational use areas;

d. state and national boundaries; and

e. potential problem areas.

Some 50 sampling stations were established when the program started, October 1, 1957. The number has now grown to over 130. Locations of sampling stations in operation as of May 1967 are shown in Figure 1.

Water Quality Parameters

In the assessment of water quality, all of the legitimate purposes for which raw waters can be used, and which may be affected by pollution, must be considered. These uses may range from navigation requiring the minimum in water quality to certain industrial processing demanding the ultimate in water quality. Standards differ considerably, therefore, according to water use. For domestic use, water must be clear, colorless, free of taste, odor, disease-producing organisms and toxic compounds, and have a relatively low dissolved mineral content. Agricultural water is judged

FIGURE 1. FWPCA WATER QUALITY SURVEILLANCE SYSTEMS MAY, 1967

primarily on its mineral content, especially with respect to the ratio of sodium to other cations, and the presence of boron. Water for fish propagation and recreational purposes must be substantially free from domestic and industrial pollution and must be able to sustain an active flora of the smaller aquatic organisms on which fish and wildlife feed. Industrial water quality demands run the gamut from the complete absence of minerals to a requirement of low temperature, the critical factor in water used for cooling. The effects of radioactive materials on these uses have not been fully appraised.

Water quality data which compare favorably with goals identified in the water quality standards are the ultimate quantitative check on pollution control progress. Thus, analytical determinations made on Surveillance Program samples include such parameters as:

1. Radioactivity
   (a) Gross alpha
   (b) Gross beta
   (c) Strontium 90
2. Plankton populations
3. Coliform organisms
4. Organic chemicals including pesticides
5. Biochemical, chemical and physical measurements including trace metals.

Not all determinations are made on every sample. New parameters which are developed and found to be significant are included as the program continues.

The Significance of Trace Metals

The spectrographic analysis of water commonly reveals the presence of a number of elements, in trace amounts. The role of these minor elements in human metabolism is not completely understood, but much progress has been made in this direction by biochemists, physicians, and public health scientists. For instance, cobalt, copper and zinc are believed essential to a healthy body, whereas forms of arsenic and lead are known to be extremely toxic.

The 1968 Water Quality Criteria[1] report discusses the significance of a number of trace metals and attempts to set limiting standards insofar as they affect public water supplies, see Table I, aquatic life, agricultural uses and industry.

In many instances, however, actual limits could not be set. For example, in determining water quality requirements for aquatic life and wildlife, it is essential to recognize that there are not only acute and chronic toxic levels but also tolerable, favorable, and essential levels of dissolved materials. One must also take into consideration the fact that different species and different developmental or life stages of the same or different species may differ widely in their sensitivity or tolerance to different materials. Also substances in suspension as well as in solution may affect aquatic organisms both directly and indirectly. The problem is further complicated in that the safe level also depends on the other water quality characteristics. There are many situations, for example, where as little as ten or fifteen $\mu g/l$ of copper is the maximum safe level for aquatic life. In many cases, however, the safe levels have not as yet been accurately determined.

TABLE I

Surface Water Criteria for Trace Elements in Public Water Supplies[1]

Metal	Permissible Criteria, mg/l	Desirable Criteria, mg/l
Arsenic	0.05	absent
Barium	1.0	"
Boron	1.0	"
Cadmium	0.01	"
Chromium^{+6}	0.05	"
Copper	1.0	Virtually absent
Iron (filterable)	0.3	"
Lead	0.05	absent
Maganese (filterable)	0.05	"
Selenium	0.01	"
Silver	0.05	"
Zinc	5	Virtually absent

Absent – The most sensitive analytical procedure in Standard Methods[3] (or other approved procedures) does not show the presence of the subject constituent.

Virtually absent – This terminology implies that the substance is present in very low concentrations and is used where the substance is not objectionable in these barely detectable concentrations.

With regard to agriculture, variations and interactions of soils, plants, water and climate preclude the establishment of a single set of criteria to evaluate all water quality characteristics. Toxic limits for trace elements which would be generally applicable to all soils and all crops are not easily defined. In general, trace element tolerances for irrigation waters are much higher than for other farmstead uses.

Industrial uses present much the same problem, inasmuch as water that meets the standard for the textile industry may not be acceptable to the food canning industry, and so on. However, industrial requirements are not nearly as stringent as those for public water supplies. In the majority of instances, a water that meets the criteria for public water supplies, as shown in Table I, will also be acceptable for fish and aquatic life, livestock and other agricultural uses as well as for industrial uses. In general, the criteria for public water supplies are much the same as those given in the 1962 revised USPHS Drinking Water Standards.[2] This document states: "Substances which may have a deleterious physiological effect, or for which physiological effects are not known, shall not be introduced into the (water) system in a manner which would permit them to reach the consumer."

Among the listed materials that fall into the trace metal category and that may be measured spectrographically are arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), silver (Ag), and zinc (Zn). Other trace metals also occur at varying frequencies in river waters and may be of significance, even though their roles in physiologic processes are not yet understood. For this reason, in addition to those already listed, boron (B), molybdenum (Mo), aluminum (Al), beryllium (Be), nickel (Ni), cobalt (Co), vanadium (V) and strontium (Sr) are also routinely monitored in FWPCA's current program.

When the Surveillance System initiated the routine measurement of these trace elements, it was concerned

primarily with elements in solution because any suspended material would be removed before it reached the consumer. While the philosophy of this approach is valid, it does not measure the total trace element load in the stream. It should be emphasized at this point, and strongly so, that very little is known about the trace elements associated with river-borne suspended matter. Water quality criteria selected for trace elements in solution ignore or overlook the possibility of trace metals in the sediment load. Current laboratory practices are to analyze both the dissolved, as well as the suspended, fraction.

Detection and Measurement of Trace Metals

The detection and measurement of trace metals can be quite difficult with colorimetric analytical procedures because they are not adapted to large numbers of samples and in some cases do not possess the required sensitivity. The spectrographic procedure for routine monitoring of raw waters is, however, admirably suited to the purpose, as a large number of elements can be run simultaneously with a great degree of accuracy. Indeed, the data presented show that routine monitoring and reporting of trace metals yield water quality information hitherto available only on a limited basis. It is possible, by judicious sample collection, to pinpoint the exact source of a particular pollution problem, and to quickly identify violations of established water quality standards[4].

---

*(The dissolved solids consist for the most part of salts of sodium, potassium, calcium and magnesium; it is these materials for which a later correction must be made.)

Trace elements, whether in raw or finished water, are generally present in concentrations too low to be measured directly with the spectrograph. A means of concentrating, therefore, is necessary before the examination can be completed. Concentration can be accomplished in several ways, including evaporation,[5] precipitation,[6] and ion exchange[7]. Similarly, a correction must be made for elements that occur in gross amounts: sodium, potassium, calcium and magnesium.

To obtain the data presented in this report, weekly samples received from the various stations were composited for three-month periods. This compositing operation was performed twice a year. On occasion, monthly composites were also analyzed. The composited samples were passed through a membrane filter, having a pore size of 0.45 micron, to remove suspended matter. Total dissolved solids were then measured and an aliquot of the composited sample, chosen to contain 100 mg of solids, was evaporated to a final volume of 5.0 ml (20,000 mg/l of dissolved solids*). All samples, therefore, had the same final salt concentration, but the procedure produces varying levels of sensitivity for different sources because of the dissimilar initial volumes. Thus, the limit of detection for trace elements in the Columbia River is lower than for the Missouri River because the low dissolved solids in Columbia River water permit a larger volume of sample to be evaporated.

This might be best explained by examining the detection limits shown in Table II. For convenience, 400 mg/l was arbitrarily chosen as an average TDS content of surface waters and the detection limits as shown are based on this figure. For a water of only 200 mg/l TDS, the limit would be halved; conversely, if the TDS is 800 mg/l, the limit is doubled.

TABLE II. DETECTION LIMITS*, μg/l

Zinc	20	Copper	10
Cadmium	20	Silver	2
Arsenic	100	Nickel	20
Boron	10	Cobalt	20
Iron	10	Lead	40
Molybdenum	40	Chromium	10
Manganese	10	Vanadium	40
Aluminum	40	Barium	2
Beryllium	0.1	Strontium	4

*In a water having a TDS of 400 mg/l

The term "detection limit" is used to indicate the lowest concentration of the material that can be distinguished from background noise or interference. The limits, as shown in the table, are based on practical observations and are not mathematically contrived figures based on signal-to-noise ratios or other formulas.

For analysis of waters in relation to the Water Quality Criteria[1] for drinking water and most other uses, the evaporation method is adequate. Only a comparatively few waters exceed 400 mg/l TDS and, of course, 500 mg/l TDS is the acceptability limit for drinking water and irrigation water used on sensitive crops.

When an element has not been positively identified in a sample, the detection limit, preceded by a "less than" sign (<), is used to report the analysis. Failure to detect a particular element does not mean that the element is absent; it may be present in the original sample but at some concentration below the stated detection limit. Only positive occurrences were used to calculate the mean values shown in the various tables.

Standard solutions used for the construction of analytical curves, contain measured amounts of the elements under examination and fixed amounts of sodium, potassium, calcium and magnesium, which elements were added in concentrations approximating the average composition of United States waters[8]. The addition of the matrix elements to the standards compensates for interferences caused by the same elements in the samples and leads to improved accuracy of the data. The complete spectrographic procedure has been published previously[9].

Although other procedures may be capable of better sensitivity, this method does permit routine examination of the large number of samples required by the surveillance system operation, an accomplishment not possible with other slower and more tedious methods.

Occasionally, it does become necessary to measure trace elements accurately in highly mineralized samples. In such instances an extraction procedure[10] using a liter sample is employed. This procedure is more involved and does not recover all of the 19 elements programmed on the DR spectrograph. It does, however, have the advantage of pushing the detection limits for the extractable metals even lower.

Trace Elements in Waters of the United States

Table III lists dissolved trace elements in waters of the United States as determined from the analysis of over 1,500

samples. The minimum, maximum and mean observed values are given along with the number of positive occurrences and the frequency of detection. These data show that boron, barium and strontium were found in solution in over 98% of all samples. Zinc, iron and copper were observed with a frequency of 74 to 76%. Manganese was observed slightly less regularly at a 51% frequency and aluminum, lead, chromium, molybdenum and nickel were detected in 16 to 33% of the samples. Cadmium, beryllium, silver, cobalt, vanadium and arsenic were detected at measurable levels in less than 7% of all samples. The percent frequency and mean values by basin are given in Tables IV and V. The highest recorded concentrations are shown in Table VI. It is emphasized that data summaries for a given basin represent conditions found at the stations utilized within that basin and are not necessarily representative of the entire basin. The stations used in the collection of these data for a given basin were too few to provide values truly representative of the entire basin.

The total body of data approximates 30,000 determinations. Based on soluble trace metals, only 0.6% exceeded the limits set by the Water Quality Criteria[1] for public water supplies. Manganese was the element that most frequently violated the standards as shown in Table VII. Arsenic was second with 41; lead and iron followed with 27 and 25 respectively. Cadmium and chromium complete the list with 6 and 4 violations each. Zinc, copper, silver and barium were never observed at any station at levels which exceeded the standard.

Table VIII lists the number of violations of the standards by basins. The Ohio River Basin tops this list with 81 violations, 58 of these being due to manganese. Of 36 samples from the Monongahela River at Pittsburgh, 32 contained manganese in excess of the standards ranging from 150 to 2,150 μg/1. Also at Pittsburgh, but in the Allegheny River, 16 of 37 samples contained manganese ranging from 74 to 3,230 μg/1. Ten other manganese violations, but at lower levels, were recorded in the Ohio and Kanawaha Rivers.

Fifteen arsenic violations were also recorded in the Ohio River Basin. It is somewhat surprising that iron was never observed above 300 μg/1 in the Ohio River Basin, especially when one considers all the acid mine drainage in the area. The Southeast and Western Gulf Basins recorded 10 and 6 iron violations respectively. Of those in the Western Gulf, 5 were located in the Sabine River near Ruliff, Texas.

The Great Basin and the California Basin did not record a single observed violation over the stated time period. The Alaska Basin recorded a single manganese violation of 163 μg/1 in the Chena River at Fairbanks.

To provide data in their most useful form, the stations are grouped into their respective major river basins. These are shown in Figure 2 and the data are given in the appendix. At the beginning of each Section, summaries of trace element data for the basis are given along with a description of the basin and rivers therein. Following this, individual station summaries are presented. Only positive occurrences were used to calculate the mean values shown.

Data presented in these summaries identify concentrations of elements in solution at the time of filtration and do not provide for suspended elements or those which may have precipitated or plated out on the container walls during storage. In those instances of positive identification, therefore, the listed values are the minimum concentrations, since suspended material could increase these values considerably. This is treated more fully in another publication[11] which attempts to classify the distribution of trace elements as to the dissolved and suspended fractions.

TABLE III – SUMMARY OF TRACE ELEMENTS IN WATERS OF THE UNITED STATES*

Element	No. of Positive Occurrences	Frequency Of Detection, %	Observed Positive Values μg/l		
			Min.	Max.	Mean
Zinc	1207	76.5	2	1183	64
Cadmium	40	2.5	1	120	9.5
Arsenic	87	5.5	5	336	64
Boron	1546	98.0	1	5000	101
Phosphorus	747	47.4	2	5040	120
Iron	1192	75.6	1	4600	52
Molybdenum	516	32.7	2	1500	68
Manganese	810	51.4	0.3	3230	58
Aluminum+	456	31.2	1	2760	74
Beryllium	85	5.4	0.01	1.22	0.19
Copper	1173	74.4	1	280	15
Silver	104	6.6	0.1	38	2.6
Nickel	256	16.2	1	130	19
Cobalt	44	2.8	1	48	17
Lead	305	19.3	2	140	23
Chromium	386	24.5	1	112	9.7
Vanadium	54	3.4	2	300	40
Barium	1568	99.4	2	340	43
Strontium	1571	99.6	3	5000	217

*1,577 Samples (Oct. 1, 1962 – Sept. 30, 1967)
+1,464 Aluminum Analyses

TABLE IV

Percent Frequency of Detection for Trace Metals by Basin

	Northeast	North Atlantic	Southeast	Tennessee River	Ohio River	Lake Erie	Upper Mississippi	Western Great Lakes	Missouri River	Southwest – Lower Mississippi	Colorado River	Western Gulf	Pacific Northwest	California	Great Basin	Alaska
Zn	95.6	94.7	96.7	73.5	81.8	87.3	70.5	90.9	53.0	62.6	45.	48.9	90.1	72.4	68.4	83.3
Cd	4.4	7.6	1.1	0	2.9	8.5	1.8	3.0	0	0	1	2.1	2.5	0	5.3	0
As	5.5	7.6	8.8	1.5	8.3	4.3	7.1	4.5	2.0	1.3	2	4.3	8.6	0	5.3	16.7
B	100.	99.4	94.5	100.	99.2	100.	98.2	100.	97.3	99.4	98.	97.9	93.8	96.5	94.7	100.
P	60.4	55.6	51.6	39.7	48.8	53.2	77.7	48.5	39.5	30.3	22	23.4	52.5	62.1	26.3	55.6
Fe	87.9	78.9	98.9	83.8	68.6	66.0	80.4	78.8	66.0	80.0	59	70.2	80.2	93.1	73.7	94.4
Mo	13.2	32.7	18.7	38.2	28.1	27.7	68.8	51.5	32.0	20.0	37	10.6	38.9	37.9	57.9	27.8
Mn	50.5	48.5	72.5	57.4	58.7	61.7	61.6	5(.1	40.8	34.8	39	38.3	51.2	44.8	57.9	61.1
Al	67.0	30.4	71.4	47.1	21.5	21.3	19.6	42.4	11.6	19.4	14	21.3	30.2	17.2	15.8	27.8
Be	1.1	23.4	1.1	1.5	14.1	6.4	0	1.5	2.0	0	0	0	0.6	0	0	0
Cu	97.8	92.3	95 6	91.2	72.3	50.4	80.4	97.0	49.7	63.9	33.	40.4	87.0	69.0	73.7	94.4
Ag	14.3	5.3	5.5	0	5.4	6.4	5.4	9.1	4.1	4.5	18.	4.3	8.6	0	5.3	5.6
Ni	22.0	28.1	20.9	8.8	25.2	53.2	15.2	9.1	2.0	9.7	8.	2.1	10.5	13.8	15.8	11.1
Co	2.2	1.2	1.1	0	9.9	4.3	0.9	3.0	0.7	0.7	2.	0	3.7	0	0	0
Pb	36.3	22.2	12.1	35.3	18.6	27.7	24.1	40.9	3.4	9.7	15.	2.1	22.8	6.9	21.1	38.9
Cr	56.0	21.1	40.7	47.1	23.6	23.4	17.9	28.8	4.8	20.0	17.	6.4	32.7	20.7	10.5	22.2
V	4.4	3.5	1.1	0	3.7	4.3	0.9	0	1.4	3.9	9.	2.1	6.2	6.9	0	5.6
Ba	100.	100.	100.	100.	100.	100.	100.	100.	98.0	100.	100.	100.	100.	100.	94.7	100.
Sr	100.	100.	98.9	100.	100.	100.	100.	100.	99.3	98.7	100.	100.	99.4	96.5	94.7	100.

TABLE V

Observed Mean Positive Trace Metal Values by Basin, $\mu g/l$

	Northeast	North Atlantic	Southeast	Tennessee River	Ohio River	Lake Erie	Upper Mississippi	Western Great Lakes	Missouri River	Southwest – Lower Mississippi	Colorado River	Western Gulf	Pacific Northwest	California	Great Basin	Alaska
Zn	96	49	52	28	81	205	45	24	39	85	51	92	40	16	44	28
Cd	5	3	5	–	7	50	6	5	–	–	2	10	5	–	1	–
As	34	47	35	50	66	308	69	37	123	91	53	22	68	–	20	34
B	32	42	29	24	67	210	105	19	154	131	179	289	30	143	84	28
P	44	48	43	42	130	153	243	31	353	81	121	173	47	83	37	40
Fe	51	19	120	37	28	35	35	22	37	69	40	173	32	46	70	25
Mo	25	33	15	25	70	68	88	28	83	95	130	24	30	45	145	17
Mn	3.5	2.7	2.8	3.7	232	138	9.8	2.3	13.8	9.0	12	10	2.8	2.8	7.8	18
Al	28	22	117	30	141	56	18	17	213	68	50	333	30	63	15	11
Be	0.02	0.12	0.05	0.16	0.28	0.17	–	0.05	0.23	–	–	–	0.02	–	–	–
Cu	15	17	14	11	23	11	14	7	17	19	10	11	9	12	12	9
Ag	1.9	0.9	0.4	–	2.1	5.3	3.4	1.4	1.2	4.3	5.8	3.5	0.9	–	0.3	1.1
Ni	8	8	4	4	31	56	15	10	5	17	12	3	10	10	4	5
Co	14	9	1	–	19	33	18	11	8	36	11		8	–	–	–
Pb	17	14	8	17	30	39	33	14	39	37	32	4	15	4	18	12
Cr	14	6	4	6	7	12	7	6	17	16	16	25	6	15	4	9
V	9	12	10	–	22	54	20	–	171	25	105	9	13	30	–	32
Ba	21	25	26	25	43	42	39	15	63	90	60	67	27	42	41	17
Sr	76	62	26	47	130	260	105	44	342	540	697	652	68	153	152	81

TABLE VI – Highest Recorded Trace Metal Concentrations By Basin

Metal	Concentration, μg/l	Basin	River
Zinc	1182	Lake Erie	Cuyahoga River at Cleveland, O.
Cadmium	120	Lake Erie	Cuyahoga River at Cleveland, O.
Arsenic	336	Lake Erie	Maumee River at Toledo, O.
Boron	1800	Colorado River	Colorado River at Yuma, Ariz.
Phosphorus	5040	Missouri River	Big Sioux River below Sioux Falls, S. Dak.
Iron	952	Western Gulf	Sabine River, Near Ruliff, Tex.
Molybdenum	1100	Southwest Lower-Mississippi	Arkansas River at Coolidge, Kans.
Manganese	3230	Ohio River	Allegheny River at Pittsburgh, Pa.
Aluminum	2760	Missouri River	Yellowstone River near Sidney, Mont.
Beryllium	1.22	Ohio River	Monongahela River at Pittsburgh, Pa.
Copper	280	Ohio River	Monongahela River at Pittsburgh, Pa.
Silver	38	Colorado River	Colorado River at Loma, Colo.
Nickel	130	Lake Erie	Cuyahoga River at Cleveland, O.
Cobalt	48	Ohio River	Allegheny River at Pittsburgh, Pa.
Lead	140	Ohio River	Ohio River at Evansville, Ind.
Chromium	112	Northeast	St. Lawrence River at Massena, N. Y.
Vanadium	300	Colorado River	Colorado River at Loma, Colo.
Barium	340	Southeast	Coosa River below Rome, Ga.
Strontium	5000	Southwest Lower-Mississippi	Arkansas River at Coolidge, Kans.

TABLE VII

VIOLATIONS OF THE WATER QUALITY CRITERIA

Metal	Limit $\mu g/l$*	No. Of Violations	Mean of those values which exceeded the limits, $\mu g/l$
Cadmium	10	6	39
Arsenic	50	41	91
Iron	300	25	>676
Manganese	50	74	>586
Lead	50	27	71
Chromium^{+6}	50	4	94
Zinc	5000	0	–
Copper	1000	0	–
Silver	50	0	–
Barium	1000	0	–

*As set by the Water Quality Criteria for Public Water Supplies.

TABLE VIII

NUMBER OF VIOLATIONS BY BASINS

Basin	Total No.	METAL					
		Cd	As	Fe	Mn	Pb	Cr
Northeast	6	1	1	2	0	0	2
North Atlantic	7	0	6	0	0	1	0
Southeast	12	0	2	10	0	0	0
Tennessee R.	2	0	1	1	0	0	0
Ohio River	81	2	15	0	58	6	0
Lake Erie	18	2	0	1	12	3	0
Upper Mississippi	11	0	3	1	1	6	0
Western Great Lakes	3	0	1	0	0	2	0
Missouri River	6	0	3	1	1	1	0
Southwest– Lower Mississippi	10	0	1	3	1	4	1
Colorado River	5	0	1	0	0	3	1
Western Gulf	6	0	0	6	0	0	0
Pacific Northwest	9	1	7	0	0	1	0
California	0	0	0	0	0	0	0
Great Basin	0	0	0	0	0	0	0
Alaska	1	0	0	0	1	0	0

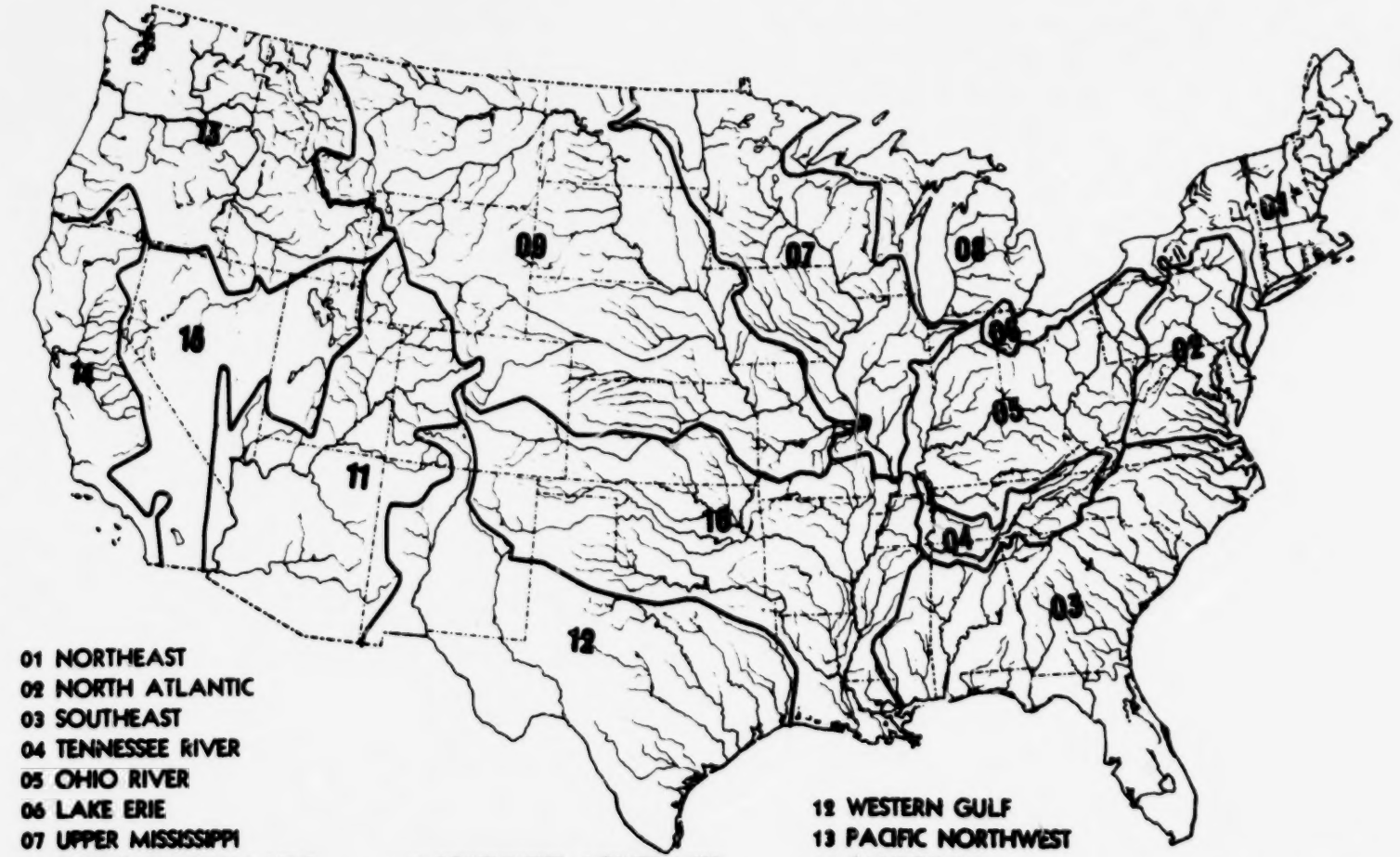

FIGURE 2 - MAJOR RIVER BASINS OF THE UNITED STATES

Current laboratory practices are to analyze both the dissolved as well as the suspended fractions. To date, this has been done for 228 samples. The data shown in Table IX compare the suspended concentrations observed in these 228 samples with the complete body of dissolved data. Note that zinc, copper and barium are found in both fractions with approximately the same frequency and at about the same mean concentration. Strontium and boron occur predominantly in solution (as do cadmium, silver, nickel, cobalt, and vanadium, when present). Iron, manganese and aluminum occur with almost 100% frequency and at considerably higher levels in the suspended fraction. Arsenic, phosphorus and molybdenum are not measured in the suspended fraction because of spectral interference from high levels of iron and aluminum. Tables X, XI and XII, which compare the dissolved and the suspended levels of iron, manganese and aluminum, are reproduced[11] to give the reader a better understanding of the "total" trace element load as determined in several selected rivers.

TABLE IX

COMPARISON OF SUSPENDED AND DISSOLVED TRACE METALS IN SURFACE WATERS

	Suspended Metals 228 samples			Dissolved Metals 1577 samples		
	No. Pos.	%F	$\overline{X}$, μg/l	No. Pos.	%F	$\overline{X}$, μg/l
Zn	146	64	62	1207	76.5	64
Cd	0	0	–	40	3	9.5
As	–	–	–	–	–	–
B	52	23	44*	1546	98	101
P	–	–	–	–	–	–
Fe	228	100	3000	1192	76	52
Mo	–	–	–	–	–	–
Mn	212	93	105	810	51	58
Al	221	97	3860	456	31	74
Be	40	18	0.34	85	5	0.19
Cu	141	62	26	1173	74	15
Ag	0	0	–	104	7	2.6
Ni	7	3	29	256	16	19
Co	0	0	–	44	3	17
Pb	5	2	120	305	19	23
Cr	18	8	30	386	25	9.7
V	0	0	–	54	3	40
Ba	216	95	38	1568	99	43
Sr	22	10	58	1571	100	217

*A single boron value of 5,500 μg/l was observed in one sample. If this value were included in the calculations, the mean suspended boron value would be 148 μg/l.

TABLE X

OCCURRENCE OF IRON

SAMPLING POINT	DISSOLVED			SUSPENDED		
	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurrence	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurrence
Delaware River						
At Martins Creek, Pa.	9	2-55	93	>105	7–>500	100
At Trenton, N. J.	7.9	3-13	67	>336	78–>750	100
At Philadelphia, Pa.	27	5-144	77	>685	120–>1,030	100
Allegheny River						
At Pittsburg, Pa.	24	5-60	73	>293	70–>500	100
Monongahela River						
At Pittsburgh, Pa.	30	9-68	73	>425	18–>2,500	100
Ohio River						
Below Addison, Ohio	25	8-70	54	>652	110–>1,500	100
Kanawha River						
At Winfield Dam, W. Va.	11	6-26	47	>268	100–>625	100
Mean	19	2-144	70	>395	7–>2,500	100

TABLE XI

OCCURRENCE OF MANGANESE

SAMPLING POINT	DISSOLVED			SUSPENDED		
	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurence	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurrence
Delaware River						
At Martins Creek, Pa.	2.9	1.3–4	40	18	3-51	93
At Trenton, N. J.	3.2	1.1–6.2	27	57	10–107	100
At Philadelphia, Pa.	4.2	3.2–5.8	31	68	29–120	100
Allegheny River						
At Pittsburgh, Pa.	>1,000	74–3,230	60	205	18–1,500	100
Monongahela River						
At Pittsburgh, Pa.	607	6.6–2,150	93	73	2–442	87
Ohio River						
Below Addison, Ohio	57	7.8–180	51	238	140–400	100
Kanawha River						
At Winfield Dam, W. Va.	44	4.6–115	87	35	2.5–84	100
Mean	>330	1–3,230	56	100	2–1,500	98

TABLE XII

OCCURRENCE OF ALUMINUM

SAMPLING POINT	DISSOLVED			SUSPENDED		
	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurrence	Average of Positive Values, μg/l	Range of Positive Values, μg/l	Percent Occurrence
Delaware River						
At Martins Creek, Pa.	14	7–22	20	83	10–285	53
At Trenton, N. J.	3	1.1–6.2	27	304	26–800	100
At Philadelphia, Pa.	29	16–41	15	690	135–1,440	100
Allegheny River						
At Pittsburgh, Pa.	72	24–120	13	205	13–575	87
Monongahela River						
At Pittsburgh, Pa.	170	30–1,875	67	73	3–442	67
Ohio River						
Below Addison, Ohio	50	50	8	563	8–1,350	100
Kanawha River						
At Winfield Dam, W. Va.	43	30–56	20	293	17–360	100
Mean	85	1–1,875	25	316	3–1,440	86

Following is a discussion of each of the elements in the spectro-chemical program including the levels that may be expected in natural waters, as well as the frequency of detection.

Zinc – As the toxicity of zinc is believed to be quite low, the USPHS Drinking Water Standards recommend a limit of 5.0 mg/l. The Water Quality Criteria[1] suggest a similar tentative limit in irrigation waters used continuously on soils. For short-term use on fine textured soils, the Criteria suggest a limit of 10.0 mg/l. The 5.0 mg/l limit is seldom reached in raw surface water, however, as zinc is absorbed to a considerable degree in hydrolyzate sediments and in soils. In the weathering process, soluble compounds of zinc are formed and the presence of traces of zinc in surface water is quite common. High zinc concentrations are found in waters having high acidity, such as in mine drainage. However, as the pH rises, the zinc concentration decreases. At very high pH levels, zinc may form anion complexes, but such conditions are not likely in natural waters.

Because of the excellent sensitivity for zinc with the direct-reading spectrometer, μg/l concentrations in waters are easily detected. Soluble zinc has been measured in over 76% of all samples at a mean value of 64 μg/l. This overall mean concentration is exceeded in five basins. Among these the highest is in the Lake Erie Basin where the mean is 205 μg/l. The percent occurrence is highest in the Southeastern Basin, where 96.7% of all samples contain this element at measurable levels; however, the mean zinc concentration is only 52 μg/l. The lowest mean value, 16 μg/l, was observed in the California Basin, where the frequency of detection is 72%.

Cadmium – While cadmium compounds are present in small proportions in many of the ores, particularly zinc ore, only minute traces are found in natural waters. If abnormally high concentrations are found, industrial pollution is probably the cause, with the electroplating plants to be suspected. Cadmium in drinking water is very toxic and as little as 0.01 mg/l is grounds for rejection of the raw supply. Tentative limits suggested by the Water Quality Criteria[1] for cadmium in irrigation waters are 0.005 and 0.05 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

In waters of normal alkalinity, the concentration of cadmium, when present, is quite low because of the low solubility of the carbonate and hydroxide. Like zinc, cadmium is largely adsorbed from solution in natural water by the hydrolyzate and oxidate sediments or precipitates as the carbonate. Cadmium was found in less than 3% of all samples, with a mean of slightly under 10 μg/l.

The Lake Erie Basin contained both the greatest frequency of detection, 8.5%, as well as the largest mean, 50 μg/l. The largest concentration ever detected was 120 μg/l in the Cuyahoga River at Cleveland, Ohio.

Cadmium was not detected in the Tennessee River Basin, the Missouri River Basin, Southwest–Lower Mississippi River Basin, the California Basin or the Alaska Basin.

Arsenic – In natural waters, trace quantities of arsenic may be fairly common. Arsenic in rock may be present as the arsenide, as native arsenic in some mineral veins and as oxides of arsenic. In natural waters, it is most often present as the anion, either as arsenate ($As\ 0_4^{---}$) or arsenite ($As\ 0_2^{-}$). Wastes from industry and mining activity, and residues from certain insecticides and herbicides, may also constitute sources of arsenic in water. Arsenates are found in certain springs and mineral wells, some reported to be as high as 4

mg/1. The PHS sets a limit of 0.01 mg/1 for drinking water with concentrations of 0.05 mg/1 grounds for rejection. Tentative limits suggested by the Water Quality Criteria[1] for arsenic in irrigation waters are 1.0 and 10.0 mg/1 for continuous use on all soils and short-term use on fine textured soil, respectively.

Arsenic is found in <6% of all samples. While the Alaska Basin shows the greatest percent frequency at 16.7, the mean concentration is 34 μg/1. The Lake Erie Basin, where arsenic occurs in 4% of the samples, has a mean concentration of 308 μg/1. This represents only two actual values of 281 and 336 μg/1, however, and may not be a fair comparison. The same is true for the Alaska Basin where figures are based on only three occurrences.

Arsenic is also found in the Southeast Basin, North Atlantic Basin, Ohio River Basin and Pacific Northwest Basin, with a frequency of 8-9%. Mean concentrations ranged from 35 to 68 μg/1 within these basins. The most significant occurrence of arsenic was in the Schuylkill River at Philadelphia, Pennsylvania, where it was detected in 50% of the samples at a mean concentration of 69 μg/1. These positive occurrences, associated with the failure of an industrial waste system, were recorded in samples taken between April 1963 and June 1965. Since that time, there were no positive occurrences of arsenic in the Schuylkill. In general, all spectrochemical arsenic observations are confirmed by wet chemical analyses.

Boron – The element boron is a minor constituent of rocks and minerals and may be carried off in solution during the weathering process. Boron is also present in volcanic emanations as the acid, H_3BO_3, or as a halogenide such as BF_3. The water of some hot springs and especially water from areas of recent volcanic activity may, therefore, be quite high in boron. Large evaporate deposits are known to exist in the closed basins of southern California and Nevada. Boron may also be added to water for cleaning operations where borates are used as detergents.

While the toxicity of boron is not completely understood, agriculturalists are concerned with boron concentrations in irrigation waters because of its relationship to plant growth. It is essential in trace quantities in plant nutrition but can be toxic to some plants at concentrations approaching 1.0 mg/1. The USPHS has issued no mandatory or recommended limits for boron in drinking water. Tentative limits suggested by the Water Quality Criteria[1] for boron in irrigation waters are 0.75 and 2.0 mg/1 for continuous use on all soils and short-term use on fine textured soil, respectively.

Soluble boron was found in 98% of all samples, generally at levels below 200 μg/1. The mean boron concentration in waters of the United States was found to be 101 μg/1. Mean basin levels ranged from a low of 19 μg/1 in the Western Great Lakes Basin to 289 μg/1 in the Western Gulf Basin. Concentrations exceeding 1 mg/1 were recorded in the Arkansas River at Collidge, Kansas, the Colorado River above Parker Dam and at Yuma, Arizona, and in the Rio Grande at El Paso, Texas.

Iron – Iron is one of the most abundant constituents of rocks and soils and, therefore, is commonly found in natural water in varying concentrations. As it is a highly objectionable constituent in water supplies, a limit of 0.3 mg/1 has been set in drinking water. This value is not based on the toxicity but rather on its undesirability for esthetic reasons. It imparts brownish color to laundered materials, stains fixtures, and affects the taste of both drinking water and beverages. Iron is not likely to be a problem in irrigation waters.

In addition to corrosion products formed by the action of metallic iron, water, and oxygen, natural waters may be polluted by iron-bearing industrial wastes, by the leaching of soluble iron salts from soil and rocks, and also by acid-mine drainage.

Iron may occur in water at two levels of oxidation, either as bivalent ferrous iron or trivalent ferric iron. The chlorides of both forms are highly soluble in water; however, the ferrous ions are readily oxidized in natural surface waters to the insoluble ferric hydroxides. These precipitates tend to agglomerate, flocculate, and settle or be absorbed on surfaces; hence, the concentration of soluble iron in well-aerated waters is generally low, rarely exceeding 200 μg/l in the rivers studied. However, the pH may be such that high concentrations of iron do occasionally remain in solution. Such is the case with the Savannah River where concentrations approaching 0.7 mg/l have been observed. High iron concentrations have also been reported in the Arkansas River at Coolidge, Kansas, the Ouachita River at Bastrop, Louisiana, the Sabine River near Ruliff, Texas and the Rio Grande at Brownsville, Texas.

Iron occurs with the greatest frequency in the Southeast Basin (No. 3) where it has been observed in solution at measureable levels in over 98% of all samples. The mean for this basin was 120 μg/l. Other mean concentrations ranged from 19 μg/l in the North Atlantic Basin to 173 μg/l in the Western Gulf Basin.

Molybdenum – Molybdenum and its salts are not considered to be significant in water pollution at the present time. Molybdenum does occur in some minerals; however, it is not widely distributed in nature. Its presence was detected in 33% of all samples at a mean level of 68 μg/l. The highest frequency of detection was in the Upper Mississippi Basin where it was found in over 68% of the samples at a mean concentration of 88 μg/l. Other mean values ranged from a low of 15 μg/l in the Southeast Basin to a high of 145 μg/l in the Great Basin. Tentative limits suggested by the Water Quality Criteria[1] for molybdenum in irrigation waters are 0.005 and 0.05 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively. Molybdenum is not included in the Standards for drinking water.

Manganese – Manganese resembles iron, both in its chemical behavior and in its occurrence in natural waters. It is, however, much less abundant in rocks than iron and, as a result, is found in water at lower concentrations. Like iron, it occurs in the bivalent and trivalent forms. The chlorides, nitrates, and sulfates are highly soluble in water, but the oxides, carbonates, and hydroxides are only sparingly soluble. In most natural waters, the concentration of manganese is less than 20 μg/l but can be higher when mining or industrial wastes are involved as is the case in both the Allegheny and the Monongahela Rivers. Manganese concentrations above 1 mg/l may also result where manganese-bearing minerals are attacked by water under reducing conditions or where certain types of bacteria are active.

Manganese frequently accompanies iron in ground waters and both are commonly reported together. As with iron, the criterion for drinking water has been established on the basis of esthetic and economic considerations rather than physiological hazards. The recommended limit for manganese is 0.05 mg/l. For irrigation waters the tentative limits suggested by the Water Quality Criteria[1] are 2.0 and 20.0 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

Of a total of over 1,500 samples, manganese was found in over 800 for a frequency of 51%. The highest mean

concentration occurred in the Ohio River Basin at 230 μg/1; however, the Southeast Basin had the highest frequency, 72%.

The presence of manganese in the Ohio River Basin (Ohio River) is due to acid-mine drainage. This discharge of acid from active or abandoned mines, particularly coal mines, is a very serious problem. Where coal is mined, an associated mineral called pyrite containing iron and sulfur is exposed to water and air. As a result of this exposure to weathering, the pyrite breaks down to form sulfuric acid and acid producing compounds of iron. Through pumping or by natural drainage, the acid wastes flow into nearby streams which are unable to neutralize these acid wastes completely, and thus become unfit for use by man, and no longer can support fish life. Both the Allegheny and the Monongahela Rivers are examples of acid streams. It has been estimated that the Monongahela empties the equivalent of 200,000 tons of sulfuric acid each year into the Ohio. However, beyond the mouth of the Muskingum River, 170 miles downstream, the acid load has been neutralized completely. In addition to the acid mine drainage, oil field brines and mill wastes are discharged into the headwaters of the Allegheny.

The highest manganese concentrations included in these data were observed in the Allegheny and Monongahela Rivers at 3.2 and 2.2 mg/1, respectively. The mean manganese concentrations in the Allegheny and Monongahela Rivers were 0.5 and 0.6 mg/1, respectively.

With a mean flow of 15,870 cfs in the Allegheny and 11,210 cfs in the Monongahela, this means, on the average, that 30 and 25 lbs, respectively, of soluble manganese pass a given point every minute in each of these rivers.

Manganese, like iron, does not remain long in solution, however, as evidenced at the first downstream station on the Ohio where the mean concentration was 68 μg/1. The highest single value at this sampling point was 376 μg/1 and the lowest 2.7 μg/1. Based on an average stream flow of 29,240 cfs, this means the soluble manganese load passing this point has been reduced to 7.4 lbs/min. The concentration of manganese in the Ohio River at Cairo, Illinois, ranged from 0.4 to 8.1 μg/1 with a mean of only 2.9 μg/1. With an average stream flow of 222,330 cfs at this station, the soluble manganese load has been further reduced to 2.5 lbs/min.

Manganese is also frequently observed at high levels in the Cuyahoga River at Cleveland, Ohio.

Aluminum – Aluminum, which is one of the most abundant elements on the surface of the earth, occurs in many rocks and ores but never as the pure metal. In the process of weathering, aluminum is highly resistant to removal by solution and remains behind permanently to form the clay minerals in soils, and the greater part of shale and similar hydrolyzate sediments. In streams, the presence of aluminum ions may result both from industrial wastes and mine drainage. While some aluminum salts are soluble, aluminum is not likely to remain in solution long as it precipitates and settles or is absorbed as the hydroxide, carbonate, etc.

Soluble aluminum has been found in waters of the United States in concentrations ranging from 1 to 2,760 μg/1 with a mean of 74 μg/1. The overall frequency of detection is 31%. The highest mean basin concentration of 333 μg/1 was observed in the Western Gulf Basin where the frequency of

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Stream loadings as shown were calculated by the following formula:

cu. ft/sec x mg/1 x 0.0037 = lbs/min.

detection is 21%. The highest frequency of detection by basin was 71% in the Southeast. The mean value for this basin was 117 μg/l.

The highest observed aluminum concentration of 2,760 μg/l was a single occurrence in the Yellowstone River near Sidney, Montana. Aluminum was also observed in the Monongahela River at Pittsburgh with a frequency of 55% in concentrations ranging from 13 to 1,430 μg/l, the mean concentration being 300 μg/l.

Aluminum in public water supplies is not a health problem, and therefore is not included in the Drinking Water Standards. Tentative limits suggested by the Water Quality Criteria[1] for aluminum in irrigation waters are 1.0 and 20.0 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

Beryllium – Beryllium is a comparatively rare element found chiefly in the mineral beryl. In the weathering process, beryllium is concentrated in hydrozates and, like aluminum, does not go into solution to any appreciable degree. Beryllium is not likely to be found in natural waters in greater than trace amounts because of the relative insolubility of the oxide and hydroxide at the normal pH range of such waters. Indeed, it was found at measurable levels in less than 6% of the samples analyzed.

Only two basins contain significant amounts of beryllium. The North Atlantic Basin mean beryllium concentration was 0.12 μg/l, with a frequency of 23%. The Ohio River Basin mean concentration was over twice this amount, 0.28 μg/l; however, the frequency was only 14%.

Three rivers are mainly responsible for these figures, the Delaware, the Monongahela and the Allegheny. Beryllium is most frequently found in the Delaware River at Trenton, New Jersey and in the Monongahela River at Pittsburgh, Pennsylvania where the frequencies are 72 and 64% respectively. Beryllium at measurable levels was found in 27% of the Allegheny samples. The mean concentration of 0.16 μg/l observed at Trenton decreases to 0.04 μg/l with a frequency of 36% by the time the Delaware reaches the Philadelphia station.

The beryllium in the Delaware has been traced to the Lehigh River, one of the tributaries. The presence of beryllium at Pittsburgh is believed to be due to the mine drainage in that area.

Beryllium concentrations in the trace range may be important because of the high toxicity of this element; however, while there are cases of beryllium poisoning due to inhalation of the dust, when taken internally through the digestive tract, beryllium does not appear harmful. Exact tolerances seem uncertain and beryllium is not included in the Standards for drinking water[2]. Criteria[1] for irrigation waters lists maximum permissible levels of 0.5 and 1.0 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

Beryllium is used primarily in metallurgy to produce special alloys, in the manufacture of X-ray diffraction tubes and electrodes for neon signs, and in nuclear reactors. Consequently, it could be added to waters by industrial waste disposal, although, unless the water maintained a low pH, it seems unlikely that much would remain in solution.

Copper – Low levels of copper are routinely observed in natural water. It is more soluble than ferric iron, and should remain in solution to a greater degree during the weathering and disintegration of rocks under oxidizing conditions.

Copper occurs in natural surface waters, in solution, generally below 20 μg/1. Thus, higher levels are generally the result of pollution, attributable to water's corrosive action on copper and brass tubing, to industiral effluents, or to the use of copper compounds for the control of undesirable aquatic organisms or plants.

The chloride, nitrate, and sulfate of bivalent copper are highly soluble in water, but the carbonate, hydroxide, oxide, and sulfide are not. Therefore, cupric ions introduced into natural waters at pH 7 or above will precipitate as the hydroxide or as basic copper carbonate and be removed by adsorption and/or sedimentation.

Soluble copper was found in over 74% of all samples at measurable levels; the mean concentration, however, was only 15 μg/1. Some of the highest values observed were in the Monongahela River where concentrations ranged from as little as 3 to 280 μg/1, with a mean of 66 μg/1. Some of the lowest values were observed in the Western Great Lakes Basin where the mean concentration was 7 μg/1 with a frequency of 97%.

Copper is an essential and beneficial element in human metabolism. Small amounts are regarded as nontoxic but large doses may produce emesis and prolonged oral administration may result in liver damage. Because copper in concentrations high enough to be dangerous to human beings renders water disagreeable to taste, it is not considered a hazard in domestic supplies. The recommended limit for copper set by the Drinking Water Standards[2] is 1 mg/1. The threshold concentrations for taste have been generally reported in the range of 1-2 mg/1, while as much as 5-7.5 mg/1 makes the water completely undrinkable. Tentative limits suggested by the Water Quality Criteria[1] for copper in irrigation waters are 0.2 and 5.0 mg/1 for continuous use on all soils and short-term use on fine textured soil, respectively.

Silver – In nature, silver is found in the elemental state and combined in several ores. From these ores, silver ions may be leached into ground and surface waters, but since many silver salts such as the chloride, sulfide, phosphate, and aresenate are insoluble, silver ions would not be expected to occur in significant concentrations in natural waters. Silver was found in <7% of all samples with a mean observed value of only 2.6 μg/1. The greatest occurrence of silver was in the Colorado River Basin where it was observed in 18% of the samples at a mean concentration of 5.8 μg/1. This was also the highest mean for any basin. Silver has never been found at measurable levels in either the Tennessee River Basin or California Basin.

Traces of silver could also be expected to reach natural waters from various manufacturing processes such as electroplating and in the processing of food and beverages.

Before 1962, silver was not included in the Drinking Water Standards. The current mandatory limit of 0.05 mg/1 was apparently set, not because of the danger of silver in natural sources of water supply, but rather to prevent its intentional addition to water, in excessive amounts, for disinfection. The limit was based on cosmetic considerations rather than public health effects. Taken into the body in sufficient concentration, silver produces a permanent blue-grey discoloration of the skin, eyes, and mucous membranes which is unsightly and disturbing to observer and victim alike. The amount of colloidal silver required to produce this condition is not known.

Nickel – Elemental nickel is seldom observed in nature; however, nickel compounds are found in many ores and minerals. While the pure metal is not soluble in water, the salts are quite soluble. In the process of weathering, nickel goes into insoluble minerals of the hydrolyzates. Any nickel

in surface or ground water is likely to be in small amounts unless present as a result of industrial pollution such as metal plating. This may explain the presence of nickel in the Lake Erie Basin where it was observed at a frequency of 53% and a mean concentration of 56 μg/1. Nickel was found in United States waters with a frequency of 16% at an overall mean concentration of 19 μg/1. While it has been observed in every basin at least once, the Missouri River and the Western Gulf Basins were lowest in frequency at 2%. They were also among the lowest in mean concentrations at 5 and 3 μg/1, respectively. The highest single recorded value was 130 μg/1 in the Cuyahoga River at Cleveland, Ohio.

The FWPCA Water Quality Criteria[1] do not place a limit on nickel in drinking water, as the toxicity is believed to be quite low. Systemic poisoning of human beings by nickel or nickel salts is almost unknown; however, it is toxic to certain plant life. For irrigation waters, the Criteria place a limit of 0.5 and 2.0 mg/1 for continuous use on all soils and short-term use on fine textured soil, respectively.

Cobalt – Cobalt is very similar in chemical behavior to nickel. It is present in igneous rocks in small amounts. In the weathering process, cobalt is taken into solution more readily than nickel but is adsorbed to a great extent by the hydrolyzate or oxidate sediments. Cobalt may also be taken into solution in small amounts through bacteriological activity similar to that causing solution of manganese.

Cobalt salts may be bivalent or trivalent. Solutions containing cobaltous ions (Co^{++}) are relatively stable but cobaltic ions (Co^{+++}) are powerful oxidizing agents and, consequently, are unstable in natural waters.

The USPHS Drinking Water Standards set no limit for cobalt as it is an essential trace element with relative low toxicity to man. A maximum safe concentration of cobalt in drinking water has not been established or estimated on the basis of present knowledge. Tentative limits suggested by the Water Quality Criteria[1] for cobalt in irrigation waters are 0.2 and 10.0 mg/1 for continuous use on all soils and short-term use on fine textured soil, respectively.

Cobalt was observed in solution in <3% of all samples ranging in concentration from 1-48 μg/1. The highest frequency of detection, 10%, occurred in the Ohio River Basin. Excluding the Southwest – Lower Mississippi Basin, where a single positive observation of 36 μg/1 was recorded, and also the Lake Erie Basin where two values of 20 and 46 μg/1 were recorded, the Ohio River Basin also had the highest mean concentration of 19 μg/1. Again, this is believed due to the presence of acid mine drainage which is prevalent in the Pittsburgh area. Observed concentrations for the Monongahela River ranged between 7-34 μg/1 with a frequency of 42% (15 of 36 samples), and a mean of 19 μg/1. Concentrations in the Allegheny ranged between 3 and 48 μg/1 with a frequency of 21% (8 of 37 samples) and a mean of 18 μg/1.

Cobalt was never detected in the Tennessee River Basin, Western Gulf Basin, California Basin, Alaska Basin or Great Basin.

Lead – Lead occurs in rocks primarily as the sulfide and also as the oxide. In areas where limestone and galena are found, natural waters are known to contain lead in solution as high as 0.4-0.8 mg/1. This is unusual, however, and lead concentrations in surface and ground waters used for domestic supplies range from traces to 0.04 mg/1 with an average around 0.01 mg/1. Lead is more likely to be introduced into water as a constituent of various industrial and mining effluents. Certain lead salts such as the acetate

and chloride are readily soluble, but because the carbonate and hydroxide are insoluble and the sulfide only slightly soluble, lead is not likely to remain long in solution in natural waters. The analyses of over 1,500 samples bear this out as lead was observed at measurable levels with a frequency of under 20%. The mean of these positive occurrences was 23 μg/l. The highest occurrence of lead was observed in the Western Great Lakes Basin where the frequency is slightly above 40%. The mean in this basin, however, was only 14 μg/l. Lead was observed in the Lake Erie Basin with a frequency of 28% (13 of 47 samples) ranging in concentration from 16 to 90 μg/l with a mean of 39 μg/l.

Because lead and its compounds are highly toxic, the mandatory limit set by the USPHS Drinking Water Standards[2] was 0.1 mg/l for many years. The 1962 Standards lowered this limit to 0.05 mg/l. Lead poisoning usually results from the cumulative toxic effects of lead after continuous consumption over a long period of time, rather than from occasional small doses. Lead is not considered essential to the nutrition of animals or human beings. Tentative limits suggested by the Water Quality Criteria[1] for lead in irrigation waters are 5.0 and 20.0 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

Chromium – In nature, chromium is present in minor amounts in igneous rocks, being more abundant in basic types than in the more silicic types of rock. In the weathering process, chromium in the cationic form (Cr^{+++}) behaves much like iron and is largely retained in the hydrolyzate. Very little chromium goes into solution unless the pH is low. Thus, natural waters would be expected to contain only traces of chromium as a cation.

The greatest frequency of detection for chromium for waters of the United States was in the Northeast Basin where it was detected in 56% (51 of 91) of all samples, ranging in concentration from 1 to 112 μg/l and having a mean value of 14 μg/l. The highest mean concentration observed for any basin was 25 μg/l in the Western Gulf. However, as only 47 samples were analyzed, of which chromium was detected in only 3, this may not be significant.

Under strong oxidizing conditions, chromium may be converted to the hexavalent state and occur as the chromate (CrO_4^-) anion. Natural chromates are rare, however, and when found in water usually indicate pollution by industrial wastes. Hexavalent chromium salts are used much more extensively in industry than the more soluble trivalent salts.

Chromium is not known to be either an essential or beneficial element in the body. When inhaled, chromium is a known carcinogenic agent; however, it is not known whether cancer will result from ingestion of chromium in any of its valence forms. At present, the level of chromate ion that can be tolerated by man without adverse health effects is uncertain. The Criteria[1] have set a limit of 0.05 mg/l for hexavalent chromium in drinking water. Trivalent chromium is not believed to be of concern in drinking water supplies. Tolerances for chromium in irrigation waters are 5.0 and 20.0 mg/l for continuous use on all soils and short-term use on fine textured soil, respectively.

Vanadium – While metallic vanadium does not occur free in nature, minerals containing vanadium are widespread. In its salts, it may exist in several valence states. While the tetra- and penta-salts are generally soluble, the trivalent salts are insoluble. Vanadium forms the vanadyl cation (VO), the salts of which are soluble, in addition to the anion vanadate (VO_4). Any vanadium salts occurring in wastewater are likely to remain in solution.

Vanadium occurs in many soils and in vegetation grown in such soils. Trace amounts of vanadium have been found in the water of the southwestern United States. Although vanadium has not been demonstrated to be essential in human nutrition, there is evidence that it has certain beneficial biological functions[12]. Vanadium is not included in the Drinking Water Standards. It is included in the Criteria[1] for irrigation water, where the tentative limit is given as 10 mg/l for continuous use on all soils as well as for short-term use on fine textured soil.

In the collection of data here reported, this metal was observed with the greatest frequency in the Colorado River Basin (9%), where the range of concentration was 7 to 300 μg/l with a mean of 105 μg/l. It was also observed in two samples from the Missouri River Basin at 158 and 184 μg/l. Vanadium has never been detected at measurable concentrations in the Tennessee River Basin, Western Great Lakes Basin, or the Great Basin. It was observed in only 54 of the more than 1,500 samples analyzed for a frequency of 3.4%.

Barium – Barium is found in nature as the sulfate and the carbonate as well as in other ores. While the carbonate and sulfate are insoluble, most other barium salts are soluble. Any barium ions discharged into natural waters, however, would be expected to be precipitated and removed by adsorption or sedimentation. Thus, barium would not be expected to be found in ground or surface waters above the trace level. Actually, however, barium was found in almost 100% of all samples. Concentrations ranged from 2 to 340 μg/l, with a mean of 43. The highest basin mean was recorded in the Southwest–Lower Mississippi where concentrations ranged between 13 and 262 μg/l with a mean of 90 μg/l. The highest individual observed value was recorded in the Coosa River at Rome, Georgia. A total of five samples from this station showed barium concentrations ranging from 27 to 340 μg/l with a mean of 107 μg/l.

Apparently no study has been made of the amounts of barium that can be tolerated in drinking water or of the effects from prolonged feeding of barium salts from which an acceptable drinking water standard may be set. Because of barium's known toxic effects on the heart, blood vessels, and nerves, the U.S. Public Health Service in 1962 set a maximum allowable limit of 1.0 mg/l. This limit was retained by the Water Quality Criteria[1] and concentrations in excess of this figure are grounds for rejection of the water supply. No limit has been set for barium in irrigation water.

Strontium – One of the most abundant minor constituents in igneous rock is strontium. It is not found free in nature but occurs largely in the form of the sulfate with calcium and barium minerals. Strontium carbonate and sulfate are only slightly soluble, thus do not occur in high concentrations in surface water. Except for the southwestern part of the United States, where concentrations of 3-5 mg/l have been observed, the mean concentrations for the soluble fraction are generally below 0.2 mg/l. Strontium was observed in the dissolved fraction in almost all samples, the frequency of detection being over 99%. The Missouri, Southwest Lower-Mississippi, Colorado and Western Gulf Basin had mean strontium concentrations of 342, 540, 697 and 652 μg/l, respectively.

Strontium does not find great industrial use. Toxicologically, no evidence has been found to show that nonradioactive strontium salts taken orally by man or animals produce harmful effects. Thus, strontium is not included in the Standards for drinking water or the Criteria[1] for irrigation water.

Summary

A nationwide surveillance program to characterize chemical and biological trends in water quality has been in progress since 1957. A part of this interdisciplinary approach to water quality assessment has been the use of a direct-reading emission spectrograph for measuring the concentrations of 19 trace elements in solution in the major rivers of the United States.

The data presented in this publication were obtained over a five-year period, October 1, 1962–September 30, 1967 and represent over 1,500 samples collected from over 130 sampling stations. Of the nineteen elements routinely sought, boron, barium and strontium occurred with a frequency of over 98%. Zinc, iron and copper were found quite frequently, being observed in about 75% of the samples. Manganese was slightly less frequent at 51%. Aluminum, lead, chromium, molybdenum and nickel varied between 16 and 33%. Cadmium, beryllium, silver, cobalt, vanadium and arsenic were detected at measurable levels in less than 7% of the samples.

Zince, iron, manganese, aluminum, beryllium, copper and chromium occurred with the greatest frequency in the Northeast, North Atlantic and Southeast Basins. Yet none of these basins contained the highest mean values for any of these elements. In general, those trace elements evaluated occurred with the greatest frequency in waters east of the Mississippi.

The data presented in these summaries include only concentrations in solution at the time of filtration. Suspended levels, either at time of collection or time of filtration, are not included. It must be emphasized, therefore, that for elements such as iron, manganese, aluminum and, in particular, lead, total stream loadings would be much higher as these elements tend to precipitate or be adsorbed by other suspended materials quite rapidly. Thus, concentrations given in the summaries for these elements should be interpreted as the minimum levels present.

In conclusion, permissible levels established by the USPHS Drinking Water Standards and the Water Quality Criteria[1] for public water supplies were exceeded in only isolated samples by soluble concentration. In all probability there were other cases where the safe levels for aquatic life were also exceeded. However, at present, levels considered as safe for aquatic life have not as yet been accurately determined. Almost certainly, streams with any degree of turbidity will contain some higher level of trace metals when total stream loading is considered.

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APPENDIXES

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INTRODUCTION

The Appendixes provide detailed summaries of the trace metals data used in the Report by basin as well as by individual station. It is again emphasized that data summaries for a given basin represent conditions found at the stations utilized within that basin and are not necessarily representative of the entire basin. The stations used in the collection of these data for a given basin were insufficient in number to provide values truly representative of the entire basin.

BASIN 1

NORTHEAST

Appendix A

Basin 1 – Northeast

The Northeast Basin is drained by many rivers. The basin includes all of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut plus most of New York. The region is generally mountainous to hilly with local coastal and interior plains. Eight Water Quality Surveillance System stations are located on six rivers.

A total of 91 samples within this basin were analyzed. Results show boron, barium and strontium present in all samples. Zinc and copper were also frequently observed (>95%). Iron and aluminum were somewhat less frequent, while manganese, lead and chromium varied between 36-56% frequency. Some of the highest zinc and chromium concentrations in the surveillance system were observed in this basin. Generally, however, basin averages were either equal to or below national averages. All elements included in the program were observed on at least one occasion. These data are summarized in the following table.

SUMMARY OF TRACE ELEMENTS

BASIN 1 – NORTHEAST

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	87	95.6	4	697	96
Cadmium	4	4.4	1	12	5
Arsenic	5	5.5	15	58	34
Boron	91	100	6	160	32
Phosphorus	55	60.4	4	232	44
Iron	80	87.9	3	520	51
Molybdenum	12	13.2	4	61	25
Manganese	46	50.5	0.3	40	3.5
Aluminum	61	67.0	1	148	28
Beryllium	1	1.1	0.02	0.02	0.02
Copper	89	97.8	2	100	15
Silver	13	14.3	0.1	6.0	1.9
Nickel	20	22.0	1	21	8
Cobalt	2	2.2	9	20	14
Lead	33	36.3	4	48	17
Chromium	51	56.0	1	112	14
Vanadium	4	4.4	8	10	9
Barium	91	100	7	52	21
Strontium	91	100	19	224	76

HUDSON RIVER BELOW POUGHKEEPSIE, NEW YORK

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	90	8	93	52
Boron	10	100	21	89	46
Iron	9	90	4	154	43
Manganese	4	40	0.6	7.0	3.3
Copper	9	90	5	72	19
Barium	10	100	11	52	34
Strontium	10	100	63	155	99
Aluminum	4	40	3	54	33
Lead	3	30	5	23	14
Chromium	6	60	2	33	11

The Hudson River heads in the Adirondack Mountains of northern New York and flows for 300 miles to the Atlantic Ocean. The lower 100 miles are tidal. Principal tributary to the Hudson is the Mohawk River which flows easterly across central New York State, converging with the Hudson at Troy. The total Hudson drainage area is about 13,000 square miles.

This station is located 70 miles above the mouth of the Hudson. Samples are collected at the intake of the International Business Machines Corporation plant. Tides influence flows and surface elevations.

While the Hudson River is considered to be highly polluted, the trace element levels at this sampling point were well below basin and national averages. Boron, barium and strontium were observed in all samples. Zinc, iron and copper were found at measurable levels in 90% of the samples. Lead, manganese, aluminum, and chromium were detected in 30-60% of the samples. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were all either absent or below the detection limits.

LAKE ERIE AT BUFFALO, NEW YORK

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min	Max.	Mean
Zinc	9	100	64	423	178
Boron	9	100	27	160	54
Iron	9	100	4	84	19
Manganese	5	55.6	0.8	8.0	2.8
Copper	9	100	10	56	24
Barium	9	100	12	35	23
Strontium	9	100	89	177	117
Cadmium	3	33.3	4	12	7
Aluminum	7	77.8	8	66	31
Chromium	4	44.4	5	10	7

The Niagara River discharges water from Lake Erie to Lake Ontario. Its most outstanding feature is Niagara Falls with a drop of about 160 feet. There is extensive hydroelectric development on this river. This sampling point is at the lower end of Lake Erie, above the beginning of the Niagara River. Samples are taken from the Buffalo minicipal water plant intake.

Nine samples were analyzed within the time period here reported, with zinc, boron, iron, copper, barium and strontium being found at measurable concentrations in all. Except for iron, averages for each of these equaled or exceeded the basin values. Measurable levels of manganese and chromium were found less frequently.

In addition to the 10 elements shown in the table, two positive occurrences each of cobalt (9 and 20 μg/l) and nickel (13 and 21 μg/l) were recorded. A single silver value of 1.8 μg/l and one for arsenic of 17 μg/l were also observed. Beryllium and vanadium were never detected.

ST. LAWRENCE RIVER AT MASSENA, NEW YORK

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	24	88.9	4	210	41
Boron	27	100	9	58	27
Iron	17	63	5	171	22
Manganese	12	44.4	0.8	7.7	2.2
Copper	26	96.3	2	23	7
Barium	27	100	16	35	24
Strontium	27	100	80	224	118
Aluminum	22	81.5	4	148	39
Silver	8	29.6	0.8	6.0	2.6
Nickel	5	18.5	5.	10	7
Lead	17	63	4	48	22
Arsenic	4	14.8	15	58	38
Chromium	18	66.7	3	112	26
Molybdenum	7	25.9	4	50	24

The St. Lawrence River originates at the Lake Ontario outflow and flows northeastward to discharge into the Gulf of St. Lawrence. The river is tidal below Quebec.

Samples are collected at the intake of the General Motors Corporation Aluminum Foundry, a few miles upstream from the point where the St. Lawrence River enters and flows exclusively through Canada. For approximately 114 miles above this point, the river forms the Canadian-United States boundary. Hydroelectric power is a major river use and the St. Lawrence is a series of impoundments from Lake Ontario to the tidal zone at Quebec. Metal reduction plants are concentrated in this area because of the available electrical power.

A wide variety of trace elements were observed at this station, lead and chromium being the most significant. While lead was observed in 63% of all samples, the measured concentrations never exceeded 48 μg/l. Chromium, however, was observed on one occasion at 112 μg/l; more recent samples show this element occurring below 20 μg/l. Silver and nickel are also frequently observed.

While cadmium, beryllium and cobalt were never observed, two occurrences of vanadium (8 μg/l each) were recorded during the period of record.

MERRIMACK RIVER ABOVE LOWELL, MASSACHUSETTS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	8	100	28	279	140
Boron	8	100	17	148	49
Iron	8	100	26	520	165
Manganese	6	75	0.7	8.3	3.4
Copper	8	100	13	100	39
Barium	8	100	9	35	18
Strontium	8	100	22	58	33
Aluminum	7	87.5	11	68	34
Nickel	4	50	1	9	3
Chromium	8	100	1	44	9

The Merrimack River begins in the White Mountains of New Hampshire and flows southward to Massachusetts where it then turns eastward to discharge into the Atlantic Ocean. The upper basin is underlain by well-weathered granites and gneiss. The total drainage is approximately 5,000 square miles and the river length is 110 miles.

This surveillance station is six miles downstream from the New Hampshire-Massachusetts State line. Samples are collected at the Lowell municipal water plant intake. Industry in this area includes electronics, shoe manufacturing, textiles and printing.

A total of seven sampies show the average zinc, copper and iron concentrations exceeded the basin averages by factors of 1.5 to 3. Chromium was detected in all samples; the average concentration, however, is below the basin average.

In addition to those elements listed, single positive occurrences of beryllium (0.02 μg/1), silver (0.3 μg/1) and molybdenum (4 μg/1) were also recorded. Cadmium, cobalt, lead, arsenic and vanadium were never detected.

CONNECTICUT RIVER

The Connecticut River is west of the Merrimack River and drains 11,300 square miles. It heads in the granites of the White and Green Mountains of New Hampshire and Vermont and flows 400 miles south to the Atlantic Ocean. The upper basin granites merge into sandstones and shale in the lower reach. The Connecticut River forms the boundary between Vermont and New Hampshire and subsequently flows through Massachusetts and Connecticut.

Three surveillance system stations are located on the Connecticut River at Wilder, Vermont, below Northfield, Massachusetts, and at Enfield Dam, Connecticut. Thirty-seven samples from these three stations were analyzed during the period of record.

The mean strontium value remained remarkably constant over the entire sampling distance. The mean zinc concentration started out quite low, but due to several slugs recorded at Northfield, the level at Enfield Dam was approximately five times as much.

CONNECTICUT RIVER AT WILDER, VERMONT

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	5	64	22
Boron	9	100	6	34	13
Iron	9	100	15	179	73
Manganese	6	66.7	0.3	2.6	1.4
Copper	9	100	12	27	17
Barium	9	100	7	22	11
Strontium	9	100	22	77	36
Aluminum	4	44.4	6	13	9
Lead	3	33.3	4	9	7

This uppermost surveillance station on the Connecticut River is 186 miles above the mouth. Samples were collected at the Wilder Dam power plant.

Zinc, boron, iron, copper, barium and strontium were detected in all samples; however, at this point of the river, only iron and copper were found at levels exceeding the national average. Manganese was observed in 67% of the samples and aluminum in 44%.

In addition to the nine elements tabulated above, two occurrences of nickel (1 and 2 μg/l), and one each of silver (0.4 μg/l), chromium (12 μg/l), and vanadium (10 μg/l) were observed during the time period. Cadmium, arsenic, beryllium and cobalt were never detected.

CONNECTICUT RIVER BELOW NORTHFIELD, MASSACHUSETTS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	11	100	20	697	204
Boron	11	100	6	29	16
Iron	11	100	5	65	33
Manganese	3	27.3	0.4	3.0	1.3
Copper	11	100	2	21	8
Barium	11	100	7	20	14
Strontium	11	100	19	62	39
Aluminum	8	72.7	1	29	11
Chromium	6	54.6	1	6	2

This station, 50 miles downstream from Wilder, Vermont, is immediately below the Massachusetts State line and monitors the effects of waste discharges from Vermont and New Hampshire. Samples are collected from the west bank immediately upstream from an abutment of the Central Vermont Railroad Bridge. Several upstream communities in both states have no sewage treatment and discharge raw sewage into the Connecticut River. Agricultural activities include dairing and potato production. There are three paper mills four miles upstream at Hinsdale, New Hampshire.

Average iron and copper levels here were one-half those recorded at Wilder, Vermont, while average manganese, boron, aluminum, barium and strontium concentrations remained nearly constant. Chromium increased in frequency from 10 to 60%; levels ranged from 1 to 6 μg/1, averaging 2 μg/1. Lead was detected on only one occasion at 10 μg/1. Zinc remained at 100% frequency of detection, increasing in average concentration by a factor of 10. Since the compositing period of July 1–September 30, 1964, when a zinc value of 700 μg/1 was recorded, the mean value has been 275 μg/1. Previously, the average was 40 μg/1. This change was not detected at the Wilder or Enfield Dam stations. In addition to elements shown in the table, single occurrences of cadmium (1 μg/1) and silver (0.1 μg/1) were recorded. Beryllium, arsenic, nickel, cobalt and vanadium were never detected.

CONNECTICUT RIVER AT ENFIELD DAM, CONNECTICUT

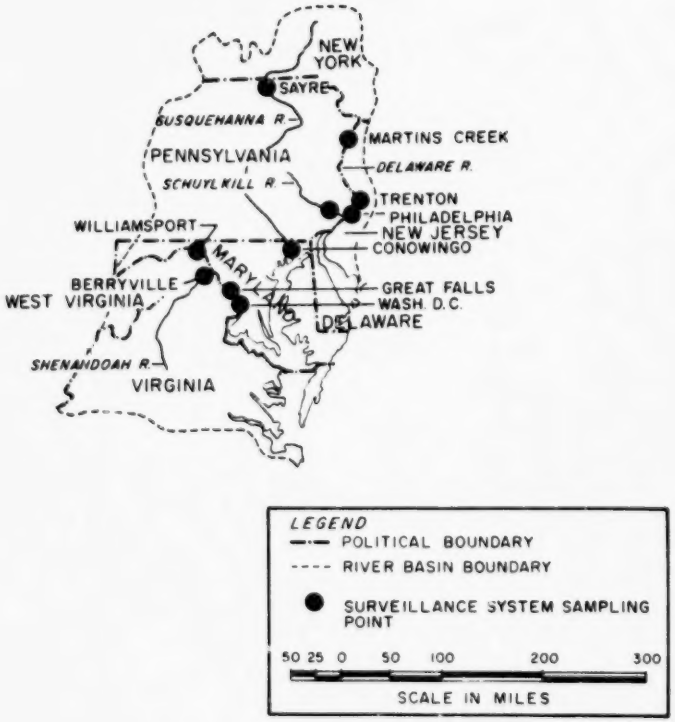
ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	17	100	17	546	104
Boron	17	100	15	92	32
Iron	17	100	3	220	47
Manganese	10	58.8	0.4	40	7.2
Copper	17	100	4	19	10
Barium	17	100	13	28	21
Strontium	17	100	23	66	38
Aluminum	9	52.9	6	36	18
Nickel	7	41.2	2	20	10
Lead	6	35.3	5	13	8
Chromium	8	47.1	2	30	10

This is the terminal surveillance station on the Connecticut River, 8 miles below the Connecticut–Massachusetts State line and 73 miles below Northfield. Many of the larger Massachusetts communities in the area treat their sewage before discharge, but several small cities do not. Broad-leaf tobacco and truck gardening are the agricultural activities in the area. Samples are collected at the dam.

Boron, iron, manganese, barium, aluminum and chromium showed slight increases in concentration over levels recorded at Northfield. Strontium remained unchanged over the sampling distance. Single occurrences of vanadium at 10 μg/l and silver at 1.8 μg/l were recorded. Cadmium, arsenic, beryllium and cobalt were never detected at this station.

BASIN 2

NORTH ATLANTIC



APPENDIX B

BASIN 2 – NORTH ATLANTIC

The North Atlantic Basin contains 10 Water Quality Surveillance Stations in three major river systems. There are three stations each on the Delaware and Potomac Rivers, two on the Susquehanna, and one each on the Schuylkill and the Shenandoah Rivers.

A total of 171 samples from this basin was analyzed, October 1, 1962–September 30, 1967. Barium and strontium were found in all samples, while boron, zinc and copper were observed at measurable levels in over 92%. Iron was slightly less regular at 79%, with manganese observed in 48% of the samples. Aluminum, lead and chromium were detected in less than 30% of the samples.

Beryllium, while detected in only 23% of the basin samples, was found in almost 40% of the Delaware River samples. At Trenton, New Jersey, beryllium occurred in 72% of the samples.

Generally, basin levels were well below national averages. All elements included in the spectrographic program were observed at measurable levels at least once. A summary of trace elements is shown in the following table.

SUMMARY OF TRACE ELEMENTS

BASIN 2 – NORTH ATLANTIC

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	162	94.7	3	504	49
Cadmium	13	7.6	1	7	3
Arsenic	13	7.6	10	97	47
Boron	170	99.4	2	221	42
Phosphorus	95	55.6	4	288	48
Iron	135	78.9	1	195	19
Molybdenum	56	32.7	4	168	33
Manganese	83	48.5	0.3	17	2.7
Aluminum	52	30.4	2	136	22
Beryllium	40	23.4	0.02	0.4	0.12
Copper	159	92.3	2	155	17
Silver	9	5.3	0.3	2.5	0.9
Nickel	48	28.1	1	49	8
Cobalt	2	1.2	6	13	9
Lead	38	22.2	3	72	14
Chromium	36	21.1	1	29	6
Vanadium	6	3.5	5	40	12
Barium	171	100	3	64	25
Strontium	171	100	4	270	62

DELAWARE RIVER

The Delaware rises in the western slope of the Catskill Mountains of east central New York and flows southerly into Delaware Bay. The Delaware forms the State boundary between New York and Pennsylvania and between Pennsylvania and New Jersey. The lower reach is polluted by industrial and municipal wastes.

Three surveillance stations are located on the Delaware River. The uppermost station is at Martins Creek, Pennsylvania, 197 miles above the River's mouth. The others are at Trenton, New Jersey, 63 miles downstream, and Philadelphia, Pennsylvania, approximately 90 miles from where the river empties into Delaware Bay.

Except for isolated instances of high zinc and iron concentrations (100–200 μg/l), the trace element mean concentrations in the Delaware were generally below national averages. Some of the less frequently detected elements, such as cadmium, silver and chromium, occurred with more regularity in the Delaware. Also, the Delaware was one of the few streams where beryllium was routinely observed. The Lehigh River appeared to be the source of this element, as beryllium levels below the Lehigh's confluence with the Delaware were higher than at Philadelphia.

DELAWARE RIVER AT MARTINS CREEK, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	36	100	9	119	44
Boron	35	97.2	2	119	18
Iron	32	88.9	2	195	19
Manganese	19	52.8	0.5	6.3	2.3
Copper	35	97.2	4	48	25
Barium	36	100	3	56	23
Strontium	36	100	4	68	30
Beryllium	2	5.6	0.03	0.04	0.04
Aluminum	5	13.9	7	22	12
Nickel	26	72.2	1	49	9
Chromium	10	27.8	2	8	3
Lead	10	27.8	3	25	10
Molybdenum	5	13.9	11	22	16
Cadmium	5	13.9	1	5	3

This sampling point is at the intake of the Martins Creek Steam Electric Generating Station of the Pennsylvania Power and Light Company on the west bank approximately 11 miles upstream from Easton, Pennsylvania.

In addition to elements tabulated above, two silver values of 0.3 and 0.5 μg/l, two arsenic values of 10 and 67 μg/l and one cobalt value of 6 μg/l were recorded. Vanadium was never detected.

DELAWARE RIVER AT TRENTON, NEW JERSEY

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	35	97.2	3	97	28
Boron	36	100	10	190	37
Iron	26	72.2	3	82	10
Manganese	27	47.2	0.4	6.2	2.1
Copper	36	100	3	25	8
Barium	36	100	4	47	24
Strontium	36	100	24	103	46
Beryllium	26	72.2	0.03	0.40	0.16
Aluminum	15	41.7	2	32	11
Silver	4	11.1	0.6	2.5	1.1
Nickel	11	30.6	1	10	4
Chromium	9	25	2	25	7
Lead	7	19.4	5	32	14
Molybdenum	16	44.4	4	86	27
Cadmium	6	16.7	2	7	4

This sampling point is at the intake of the Trenton water filtration plant, which serves a population of over 180,000. The river at this point is affected by flows from the Lehigh River, 49 miles upstream, which receives industrial discharges and treated municipal wastes from Allentown and Bethlehem, Pennsylvania.

A wide variety of trace elements were observed at this station as shown in the table. Vanadium and cobalt were never detected; and only a single arsenic occurrence of 32 μg/l was recorded.

DELAWARE RIVER AT PHILADELPHIA, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	33	100	4	178	32
Boron	33	100	7	161	58
Iron	28	84.9	1	144	24
Manganese	17	51.5	0.3	6.0	2.1
Copper	33	100	2	23	6
Barium	33	100	5	42	25
Strontium	33	100	24	97	47
Beryllium	12	36.4	0.02	0.09	0.04
Aluminum	10	30.3	3	41	15
Nickel	5	15.2	1	14	5
Chromium	7	21.2	2	29	7
Molybdenum	17	51.5	5	56	23

This station is located at the northeastern city limits of Philadelphia, approximately 90 miles from where the river empties into Delaware Bay. Samples are taken at the intake of the Torresdale municipal water plant. The river at this point is the State border between Pennsylvania and New Jersey and is subject to tidal influence.

The Delaware River in the vicinity of this station flows through a heavily populated and industrialized area and is used extensively for water supply and waste disposal. Agricultural activity in upstream areas is extensive with row crops, livestock and dairy farming predominating.

Elements observed at measurable levels other than those shown were as follows: vanadium (5 and 7 μg/l), silver (1.3 μg/l), arsenic (20 and 90 μg/l), and cobalt (13 μg/l). Cadmium was never detected.

SCHUYLKILL RIVER AT PHILADELPHIA, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	100	22	504	118
Boron	8	100	35	221	112
Iron	6	75	6	70	22
Manganese	3	37.5	1.7	17.0	7.2
Copper	8	100	5	24	15
Barium	8	100	6	37	28
Strontium	8	100	70	167	106
Lead	3	37.5	10	72	30
Molybdenum	5	62.5	21	126	64
Arsenic	4	50	30	97	69

The Schuylkill River is a major tributary to the Delaware. It is the source of intake for the Philadelphia Water Department's Schuylkill plant which is located two miles above Fairmont Dam. This point is near Philadelphia's northwest city limits and approximately 10 miles above the Schuylkill's confluence with the Delaware.

Above the station are a number of moderate sized cities whose industrial and municipal effluents affect the water characteristics. Five major upstream communities are Reading, Pottstown, Norristown, Phoenixville and Conshohocken. The estimated population served by sewage treatment plants in these cities in 1962 was 243,000. The upper reaches of this river flow through anthracite coal mining areas.

The boron concentrations at this station increased sevenfold over the period of record. A zinc value of 500 µg/l was observed. In addition to those elements tabulated, two positive occurrences of nickel (8 and 41 µg/l), one of silver 1.2 µg/l), and one of chromium (11 µg/l) were recorded. Cadmium, beryllium, cobalt and vanadium were never detected.

SESQUEHANNA RIVER

The Susquehanna River is the largest stream in the United States discharging to the Atlantic Ocean. It heads in the State of New York and flows in a southerly course across Pennsylvania to discharge into the head of Chesapeake Bay. Surveillance stations are located near the points where the river enters and leaves Pennsylvania.

Nine samples taken at each of these stations showed the boron, barium and copper levels remained constant. Beryllium and cobalt were never detected in the Susquehanna River.

SUSQUEHANNA RIVER AT SAYRE, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	39	240	102
Boron	9	100	16	150	53
Iron	8	88.9	3	122	25
Manganese	4	44.4	0.8	2.6	1.7
Copper	9	100	4	16	9
Barium	9	100	18	45	26
Strontium	9	100	29	106	49
Lead	6	66.7	3	35	15
Chromium	5	55.6	1	21	7
Aluminum	4	44.4	18	60	34

The Susquehanna enters Pennsylvania just upstream from this sampling station at the intake of the Sayre municipal water treatment plant. The drainage basin upstream from this station, in the State of New York, comprises some 6,270 square miles. A number of small New York communities lying short distances upstream from the station discharge both municipal and industrial wastes into the river. The largest upstream communities discharging sewage treatment plant effluents into the river or tributary are Elmira, New York, with a population of 46,500 located 26 miles upstream, and Binghamton, New York, population 82,000, located 51 miles upstream.

The mean zinc concentration observed at this station was approximately four times that at Conowingo. Other elemental levels remained approximately equal. In addition to those elements shown above, single cadmium (2 μg/l), arsenic (10 μg/1), nickel (7 μg/1) and vanadium (13 μg/1) values were observed. Beryllium, silver and cobalt were never detected.

SUSQUEHANNA RIVER AT CONOWINGO, MARYLAND

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	12	44	23
Boron	9	100	19	144	51
Iron	8	88.9	4	52	15
Manganese	8	88.9	0.5	11	4.8
Copper	7	77.8	2	28	9
Barium	9	100	6	46	21
Strontium	9	100	47	165	97
Lead	2	22.2	3	29	16
Molybdenum	7	77.8	6	168	65

The sampling point at this station is located at the Conowingo hydroelectric power plant a few miles downstream from the Pennsylvania–Maryland State line and 10 miles above the river's entry into Chesapeake Bay. The watershed upstream from the station, in Pennsylvania, includes a highly populated and industrialized area. There are, however, no known significant pollution sources in the immediate vicinity of the station. To supplement its present water supply, the city of Baltimore, Maryland, is constructing an intake about one-quarter mile upstream from the station.

In addition to those elements listed in the table, a positive silver value of 0.6 μg/l and a vanadium value of 6 μg/l were recorded. Cadmium, beryllium, arsenic, nickel and cobalt were never detected.

THE POTOMAC RIVER AT WILLIAMSPORT, MARYLAND

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	5	45.5	4	58	20
Boron	11	100	10	58	29
Iron	10	90.9	5	101	20
Manganese	3	27.3	0.6	4.0	2.5
Copper	5	45.5	2	11	6
Barium	11	100	5	64	31
Strontium	11	100	55	240	130
Aluminum	5	45.5	3	61	28

The Potomac River drains the eastern slope of the Allegheny Mountains and, for a large portion of its length, is the interstate boundary separating Maryland and Virginia. The headwaters are in mountainous terrain. Williamsport, Maryland, is the uppermost surveillance system station on the Potomac River. It is located at the Hagerstown, Maryland, municipal water treatment plant intake, 210 miles above the point where the river discharges to Chesapeake Bay.

This station had one of the lowest percent (45) frequencies for zinc of all stations surveyed. In general, all trace elements were below both basin and national levels. Two lead values of 5 and 6 μg/l and a single arsenic of 61 μg/l were recorded in addition to those elements shown. Cadmium, beryllium, silver, nickel, cobalt, chromium and vanadium were all either absent or below the minimum detectable limits.

POTOMAC RIVER AT GREAT FALLS, MARYLAND

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	8	88.9	8	20	12
Boron	9	100	5	71	35
Iron	6	66.7	2	123	28
Manganese	4	44.4	0.8	2.1	1.6
Copper	7	77.8	4	11	7
Barium	9	100	17	57	32
Strontium	9	100	40	168	96
Aluminum	6	66.7	17	136	46
Lead	3	33.3	3	25	16
Molybdenum	3	33.3	6	32	15

This sampling point is located 84 miles below Williamsport, Maryland, approximately 10 miles northwest of the District of Columbia boundary and is at the intake of the Dalecarlia Water Treatment Plant. This 300 mgd plant is operated by the Corps of Engineers to provide municipal water supply for the District of Columbia. The Potomac River is tidal below this station.

While the frequency of detection for zinc increased at Williamsport over the time period involved, the average concentration decreased. In addition to elements shown above, two nickel values (2 and 6 μg/l) and single cadmium (2 μg/l), arsenic (21 μg/l), and vanadium (6 μg/l) values were recorded. Beryllium, silver and cobalt were never detected.

POTOMAC RIVER AT WASHINGTON, D.C.

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	6	85.7	7	240	50
Boron	7	100	10	76	31
Iron	3	42.9	11	43	26
Manganese	4	57.1	0.9	5.0	2.9
Copper	6	85.7	3	23	11
Barium	7	100	15	56	29
Strontium	7	100	60	270	124

This station is in the east hoist room of Arlington Memorial Bridge on U. S. Highway 50. The Potomac Estuary at this point has an average tidal range of about 4 feet. The water here is still within the freshwater category with chloride concentrations of about 6 to 30 mg/l.

Trace element levels at this station showed little change over the upper Potomac sampling points. Observed values are summarized in the table. Cadmium, arsenic, beryllium, silver, nickel, cobalt, and vanadium were never detected at measurable levels.

SHENANDOAH RIVER AT BERRYVILLE, VIRGINIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	13	100	40	500	136
Boron	13	100	5	180	42
Iron	8	61.5	4	70	20
Manganese	4	30.8	1.1	6.0	3.7
Copper	11	84.6	29	106	54
Barium	13	100	7	46	30
Strontium	13	100	36	135	79
Molybdenum	3	23.0	14	51	31

The major tributary to the Potomac is the Shenandoah River. There are industrial developments in the upper reaches of both rivers. Hydroelectric power plant operations on the Shenandoah exert a major influence on the flow regimen. The Berryville sampling point is at the intake of the U. S. Army Corps of Engineers pumping station.

Zinc levels at this station, which is approximately 25 miles above the Shenandoah's mouth, are almost three times higher than basin averages.

In addition to those elements listed, single observations of arsenic, nickel, lead and vanadium at 31, 9, 5 and 40 μg/l, respectively, were recorded. Beryllium, silver, cobalt and chromium were never detected.

BASIN 3

SOUTHEAST

APPENDIX C

BASIN 3 – SOUTHEAST

The Southeast Basin comprises approximately 283,000 square miles which drain toward the Atlantic Ocean south of the Potomac Basin or into the Gulf of Mexico east of the Mississippi River Delta. Headwaters and upper reaches of the major streams are in the Appalachians. Lower reaches are in the Coastal Plain.

There are 10 Water Quality Surveillance System stations located on seven rivers within this basin. Composite samples from the basin analyzed during the time period involved totaled 91. All elements included in the spectrographic program were observed on at least one occasion. Cadmium, beryllium, cobalt and vanadium were the lesser observed elements, occurring with a frequency of only 1.1%. Only barium occurred with a frequency of 100%; five other elements were observed at measurable levels in more than 94% of all samples. The basin's mean values for both iron and aluminum exceeded the national averages by a factor of two. All other elements were either equal to, or below, national averages.

SUMMARY OF TRACE ELEMENTS

BASIN 3 – SOUTHEAST

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	88	96.7	4	495	52
Cadmium	1	1.1	5	5	5
Arsenic	8	8.8	5	109	35
Boron	86	94.5	6	120	29
Phosphorus	47	51.6	4	120	43
Iron	90	98.9	4	660	120
Molybdenum	17	18.7	2	53	15
Manganese	66	72.5	0.4	37.4	2.8
Aluminum	65	71.4	4	1050	117
Beryllium	1	1.1	0.05	0.05	0.05
Copper	87	95.6	3	110	14
Silver	5	5.5	0.1	0.7	0.4
Nickel	19	20.9	2	17	4
Cobalt	1	1.1	1	1	1
Lead	11	12.1	3	21	8
Chromium	37	40.7	1	22	4
Vanadium	1	1.1	10	10	10
Barium	91	100	3	340	26
Strontium	90	98.9	7	77	26

CHATTACHOOCHEE – APALACHICOLA RIVERS

The Chattahoochee River heads in northern Georgia. Its lower 140 miles form the Georgia-Alabama boundary. A system of locks and dams regulate the river stages and the stream is navigable up to Columbus, Georgia. The Chattahoochee joins the Flint River in Lake Seminole behind Jim Woodruff Dam to form the Apalachicola River which flows south across Florida and into the Gulf of Mexico.

There are three surveillance stations on this River: at Atlanta 300 miles above the mouth, at Lanett, Alabama approximately 100 miles downstream, and at Columbus 35 miles farther downstream.

Some of the largest iron and aluminum concentrations were found in this river system, usually in the fall and winter months.

CHATTAHOOCHEE RIVER AT ATLANTA, GEORGIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	10	100	5	46	19
Boron	10	100	6	75	19
Iron	10	100	4	225	86
Manganese	8	80	0.7	4.1	1.7
Copper	10	100	5	30	12
Barium	10	100	3	56	16
Strontium	10	100	11	40	19
Molybdenum	5	50	3	53	17
Aluminum	8	80	5	405	72
Nickel	6	60	2	17	6
Chromium	8	80	1	18	5

Samples are collected from the municipal water treatment plant intake approximately 200 feet upstream from the junction of Peachtree Creek and the Chattahoochee River. Morgan Falls' hudroelectric plant is 10 miles upstream and Sidney Lanier Reservoir 48 miles upstream from the station. The City of Atlanta and nearby Cobb, DeKalb, and Gwinnet Counties utilize the river as their water supply.

The lowest iron concentrations in the Chattahoochee River system were found at Atlanta. Cadmium, beryllium, silver, cobalt, lead and vanadium have never been observed at measurable levels at this station. A single arsenic value of 5 μg/l was recorded.

CHATTAHOOCHEE RIVER AT LANETT, ALABAMA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	8	100	8	459	81
Boron	7	87.5	24	45	34
Iron	8	100	8	174	54
Manganese	4	50	0.8	2.5	1.4
Copper	8	100	4	11	6
Barium	8	100	10	38	18
Strontium	8	100	7	33	19
Aluminum	5	62.5	19	170	78
Nickel	3	37.5	2	6	3
Chromium	3	37.5	1	12	6

This sampling point is the raw water intake for the West Point Manufacturing Company near the Georgia-Alabama State line. The City of Lanett, Alabama receives its water supply from the same source. Approximately 19 miles downstream from this station is the dam for Bartletts Ferry Reservoir constructed by the Georgia Power Company. Upstream municipal discharges include both raw sewage and secondary effluent. The cities of Lanett, Alabama and West Point, Georgia obtain their water supplies from the Chattahoochee in this vicinity.

While the mean iron concentration was somewhat lower than that observed at Atlanta, the aluminum value remained unchanged. The higher values were recorded during the fall and winter months. A single zinc value in excess of 400μg/l was also recorded. Cadmium, arsenic, beryllium, silver, cobalt and lead were never detected. Single positive occurrences of vanadium (10 μg/l) and molybdenum (11 μg/l) were recorded.

CHATTAHOOCHEE RIVER AT COLUMBUS, GEORGIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	10	100	5	154	34
Boron	10	100	17	97	32
Iron*	10	100	4	200	66
Manganese	7	70	0.4	6.3	2.6
Copper	10	100	4	44	11
Barium	10	100	8	69	22
Strontium	10	100	12	30	20
Aluminum*	5	50	5	345	96
Chromium	5	50	1	2	1

This sampling point is the Columbus municipal water treatment plant intake located in Lake Oliver. The intake can be adjusted from a zero to 40 foot depth in the lake. There are no significant industrial pollution sources in the area. Both Columbus, Georgia and Phenix City, Alabama use the Chattahoochee River for their drinking water requirements.

Iron concentrations at this station varied from 4 to >360 μg/1. The fall and winter composites were usually above 100 μg/1, while spring and summer samples were below 25 μg/1. Aluminum and manganese showed this same trend; however, manganese concentrations were much lower, never exceeding 6.3 μg/1. A single nickel value of 2 μg/1 and a lead value of 21 μg/1 were recorded in addition to elements shown above. Cadmium, arsenic, beryllium, silver, cobalt and vanadium were never detected.

*Several "greater than" values were recorded but are not shown.

APALACHICOLA RIVER AT CHATTAHOOCHEE, FLORIDA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	4	36	17
Boron	9	100	12	54	27
Iron	9	100	4	170	35
Manganese	3	33.3	0.6	1.0	0.8
Copper	8	88.9	3	44	10
Barium	9	100	11	28	17
Strontium	9	100	12	25	17
Aluminum	6	66.7	6	190	45
Lead	4	44.4	4	12	6
Chromium	3	33.3	3	13	6

This station is located at the intake of the U. S. Corps of Engineers' Jim Woodruff Dam on the Georgia-Florida State line at river mile 108. The river in this area is used principally for navigation, power and recreation.

Zinc, iron and aluminum concentrations were below those observed in the Chattahoochee River, the mean values being below basin averages. In addition to those elements shown, two positive silver values (0.3 and 0.7 μg/l) and two positive nickel values (2 and 3 μg/l) were recorded. Cadmium, arsenic, molybdenum, beryllium, cobalt and vanadium were never detected.

ROANOKE RIVER AT JOHN KERR DAM, VIRGINIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	90	4	53	15
Boron	10	100	16	108	38
Iron	10	100	4	182	77
Manganese	7	70	0.4	1.9	1.0
Copper	9	90	6	16	10
Barium	10	100	14	28	21
Strontium	10	100	15	57	33
Molybdenum	4	40	3	17	9
Aluminum	6	60	6	260	97
Chromium	4	40	2	22	7

The Roanoke River begins on the eastern slope of the Appalachian Mountains in Virgina and empties into Batchelor Bay, an arm of Albermarle Sound in North Carolina. Three impoundments on this river – Kerr Dam, Roanoke Rapids Dam and Gaston Dam provide flood control and hydroelectric power. The sampling station on this river is located at the turbine intake of the Corps of Engineers' John H. Kerr Dam which, depending on the reservoir elevations, is from 40 to 80 feet below the reservoir surface. During periods of summer stratification in the reservoir, the dissolved oxygen levels are reduced.

Occasional high concentrations of iron and aluminum were observed; however, the mean values were below basin averages. Other elements were observed in quite low concentrations. Arsenic at 20 and 22 μg/l, as well as single occurrences of beryllium at 0.05 μg/l, nickel at 5 μg/l and lead at 8 μg/l were recorded. Cadmium, silver, cobalt and vanadium were never detected.

SAVANNAH RIVER AT NORTH AUGUSTA, SOUTH CAROLINA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	6	66	20
Boron	8	88.9	12	42	23
Iron	9	100	33	660	269
Manganese	9	100	1.4	6.5	3.1
Copper	9	100	15	41	27
Barium	9	100	9	40	16
Strontium	9	100	14	31	21
Molybdenum	3	33.3	10	50	29
Aluminum	8	88.9	4	1050	349

The Savannah River heads in the Blue Ridge Mountains of North Carolina. The river forms the boundary between Georgia and South Carolina. There are extensive reservoir developments in the headwaters. This sampling point is at the intake of the North Augusta's water treatment plant approximately 20 miles downstream from Clark Hill Dam and Reservoir and 200 miles above the river's mouth. The cities of Augusta, Georgia and North Augusta, South Carolina utilize Savannah River water for drinking purposes and discharge wastes (both industrial and municipal) approximately two miles below the sampling station.

Iron and aluminum levels were consistently high with iron averaging over 250 μg/l and aluminum 350 μg/l. Aluminum was observed on one occasion above 1000 g/l. Cadmium, beryllium, silver, nickel, cobalt and vanadium were never detected at measurable levels; however, single occurrences of arsenic, lead and chromium at 14, 5 and 6 μg/l, respectively, were recorded.

SAVANNAH RIVER AT PORT WENTWORTH, GEORGIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	10	90.9	4	44	15
Boron	10	90.9	14	60	26
Iron	11	100	4	483	166
Manganese	9	81.8	0.5	37.4	6.0
Copper	11	100	3	19	10
Barium	11	100	9	35	19
Strontium	11	100	18	43	24
Aluminum	7	63.6	5	118	40
Chromium	3	27.3	3	8	6

Port Wentworth, Georgia is the lower sampling point on the Savannah River, 22 miles above the river's outflow to the Atlantic ocean. The Savannah River plant of the Atomic Energy Commission lies upstream from this station. Samples at Port Wentworth are collected from a U. S. Highway 17 Bridge within the tidal estuary.

Iron concentrations at this station varied from 4 to 483 μg/1, the mean value exceeding both basin and national averages. Other elements detected were in quite low concentrations; cadmium, beryllium and vanadium were never detected. Positive nickel values of 3 and 4 μg/1 and arsenic of 10 and 15 μg/1 were recorded as were single occurrences of silver (0.1 μg/1), cobalt (1 μg/1), lead (3 μg/1) and molybdenum (5 μg/1).

ESCAMBIA RIVER AT CENTURY, FLORIDA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	10	100	6	495	155
Boron	9	90	14	37	23
Iron	10	100	93	405	204
Manganese	9	90	0.6	13.2	3.9
Copper	10	100	3	110	33
Barium	10	100	16	36	22
Strontium	10	100	9	60	25
Aluminum	9	90	16	500	130
Nickel	3	30	4	6	5
Chromium	4	40	1	6	3

This stream begins in south-central Alabama and flows southerly across Alabama and the Florida Panhandle to discharge into Pensacola Bay. Its drainage area lies between those of the Chattahoochee River to the east and the Alabama River to the west.

This station is located just below the Florida-Alabama State line. Samples are collected from State Highway 4 Bridge two miles east of Century. Waters of the Escambia River downstream from the station in the State of Florida are used mainly for recreation and industrial cooling purposes. Upstream industrial discharges include wood preservative wastes, Kraft paper mill wastes and brine wastes totaling 26,000 lbs./day of chlorides.

In addition to high levels of zinc, iron and occasional aluminum, single positive occurrences of cadmium at 5 μg/l, silver at 0.3 μg/l and molybdenum at 9 μg/l were recorded. Two arsenic values of 92 and 109 μg/l were also detected. Beryllium, cobalt, lead and vanadium were never observed.

TOMBIGBEE RIVER BELOW COLUMBUS, MISSISSIPPI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	11	471	131
Boron	8	88.9	11	38	23
Iron	9	100	68	330	168
Manganese	8	88.9	0.4	4.0	. 2.0
Copper	9	100	4	15	6
Barium	9	100	20	75	43
Strontium	9	100	33	77	51
Aluminum	7	77.8	10	278	109
Lead	3	33.3	6	13	8
Chromium	5	55.6	1	10	5

The Tombigbee River is a major tributary to the Mobile River. It begins in Northeast Mississippi and flows south – southeastward into Alabama. The surveillance system station is located approximately 11 miles south of Columbus, Mississippi a few miles from the Mississippi-Alabama State line. Samples are collected from the bank at Camp Pratt, YMCA.

In addition to those elements listed above, single positive occurrences of silver at 0.7 μg/l and nickel at 8 μg/l were also observed. Zinc, iron and aluminum averages equalled or exceeded basin values. Cadmium, arsenic, molybdenum, beryllium, cobalt, and vanadium were never detected at this station.

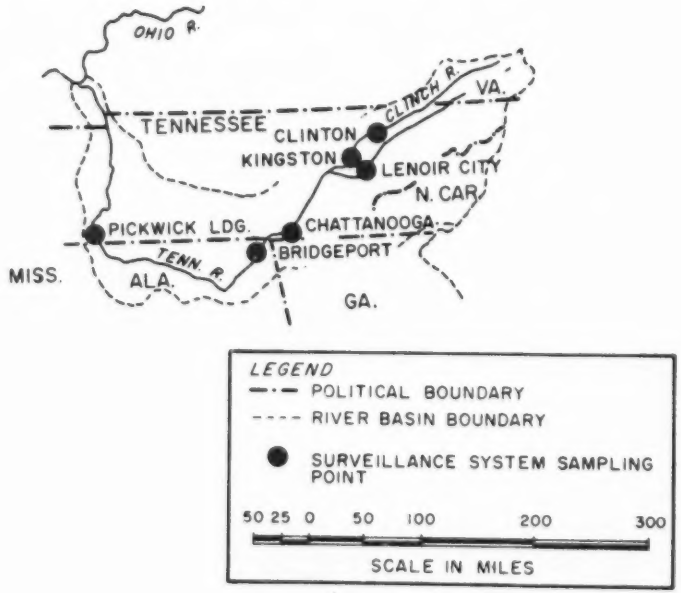
COOSA RIVER BELOW ROME, GEORGIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	4	80	6	60	26
Boron	5	100	22	120	52
Iron	4	80	6	59	24
Manganese	---	---	---	---	---
Copper	3	60	3	6	5
Barium	5	100	27	340	107
Strontium	4	80	24	36	30

This station had been operated for only three years with only five composite samples analyzed to the closing date of the time period involved in this study. Element concentrations were generally below basin and national averages. Cadmium, arsenic, molybdenum, beryllium, silver, nickel, cobalt, lead and vanadium were never observed. Chromium was detected on one occasion at 5 μg/l.

BASIN 4

TENNESSEE RIVER



APPENDIX D

BASIN 4 – TENNESSEE RIVER

The Tennessee River is formed in eastern Tennessee by the junction of the Holston and French Broad Rivers. The stream flows southwesterly across the State, westerly across northern Alabama for about 200 miles, re-enters and flows northward across Tennessee and the western tip of Kentucky to enter the Ohio River at Paducah. The total length is 652 miles. Surface water resources within the 40,910 square-mile basin have been developed by the Tennessee Valley Authority.

The Tennessee River Basin contains six Water Quality Surveillance System stations, four of these are on the main stem at Pickwick Landing, Tennessee; Bridgeport, Alabama; Chattanooga, Tennessee, and Lenoir City, Tennessee. The others are on the Clinch River above Kingston, Tennessee and at Clinton, Tennessee.

Samples analyzed within this basin during the stated time interval totaled 68. Boron, barium and strontium were observed with frequencies of 100%. Zinc, iron and copper were detected 73 to 91% of the time. Chromium and aluminum were found in 47% of the samples. while lead and molybdenum were found in approximately 37%. Nickel was observed on six occasions, ranging from 4 to 6 μg/1, while arsenic and beryllium were found at measurable levels only once. Cadmium, silver and vanadium were never detected. All basin averages generally were below national levels.

SUMMARY OF TRACE ELEMENTS

BASIN 4 – TENNESSEE RIVER

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	50	73.5	5	172	28
Cadmium	0	0	--	--	--
Arsenic	1	1.5	50	50	50
Boron	68	100	1	66	24
Phosphorus	27	39.7	6	120	42
Iron	57	83.8	2	686	37
Molybdenum	26	38.2	3	67	25
Manganese	39	57.4	0.4	11	3.7
Aluminum	32	47.1	3	92	30
Beryllium	1	1.5	0.16	0.16	0.16
Copper	62	91.2	2	33	11
Silver	0	0	--	--	--
Nickel	6	8.8	4	6	4
Cobalt	0	0	--	--	--
Lead	24	35.3	5	38	17
Chromium	32	47.1	2	20	6
Vanadium	0	0	--	--	--
Barium	68	100	2	52	25
Strontium	68	100	9	118	47

TENNESSEE RIVER AT LENOIR CITY, TENNESSEE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, $\mu g/l$		
			Min.	Max.	Mean
Zinc	8	80	11	54	32
Boron	10	100	7	30	20
Iron	8	80	4	107	34
Manganese	6	60	0.4	9.0	3.2
Copper	10	100	3	33	17
Barium	10	100	11	52	32
Strontium	10	100	20	88	63
Molybdenum	3	30	6	43	26
Aluminum	7	70	14	60	30
Lead	3	30	22	38	29
Chromium	6	60	3	10	6

This uppermost station is located 600 miles above the river's mouth. Samples are collected at the municipal water treatment plant intake. This station is one mile below, and in the tailrace of, Ft. Loudon Dam. It is almost directly opposite the mouth of a major tributary, the Little Tennessee River, which, however, probably has little influence on the water characteristics as measured at the sampling point.

The city of Knoxville, Tennessee, 50 miles upstream, discharges treated municipal wastes. The 45 mile reach of Ft. Loudon Reservoir modifies these wastes to the extent that no effect is apparent at Lenoir City. The river sustains extensive recreational use, with fishing, boating and swimming on Ft. Loudon Reservoir and excellent seasonal fisheries for sauger, walleye and white bass in the dam tailwaters.

Average trace element concentrations observed at this station approximate basin averages. In addition to elements shown above, a single positive nickel value of 6 $\mu g/l$ was recorded. Cadmium, arsenic, beryllium, silver, cobalt and vanadium were never detected.

TENNESSEE RIVER AT CHATTANOOGA, TENNESSEE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	8	61.5	9	25	16
Boron	13	100	3	50	21
Iron	12	92.3	2	73	29
Manganese	8	61.5	0.7	9.5	2.7
Copper	10	76.8	3	28	14
Barium	13	100	6	48	23
Strontium	13	100	9	70	38
Aluminum	5	38.4	19	92	37
Lead	3	23.0	10	29	19
Chromium	8	61.5	2	20	8

This sampling station is located 135 miles below Lenoir City, approximately 465 miles above the river's mouth. Samples are collected at the municipal water treatment plant intake. This station is in the tailwaters of TVA's Chickamauga Lake, approximately 48 river miles upstream from the Alabama-Tennessee State line. Hales Bar Dam is located at river mile 431, approximately 34 miles downstream from the sampling point.

Principal pollution sources above the station are a chemical plant producing fertilizers, a mineral recovery operation, and two commercial sand dredging operations which create occasional turbidity problems. The river serves as a source of municipal water supply for the city of Chattanooga. Approximately 40-45 million gallons a day are used by industry for cooling purposes. There is some commercial trotline fishing for catfish in the area, and a considerable amount of bank fishing by local residents.

The average concentrations of the elements observed generally show a slight reduction from those at Lenoir City. Beryllium was observed on one occasion at 0.16 μg/l; cadmium, arsenic, silver, nickel, cobalt and vanadium were never detected.

TENNESSEE RIVER AT BRIDGEPORT, ALABAMA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	5	55.5	6	23	12
Boron	9	100	7	45	24
Iron	9	100	4	52	21
Manganese	3	33.3	0.6	1.9	1.4
Copper	9	100	2	9	4
Barium	9	100	11	36	24
Strontium	9	100	20	118	54
Aluminum	6	66.7	16	53	28
Chromium	3	33.3	3	13	6

This station, 408 miles above the mouth of the Tennessee River, is located at TVA's Widows Creek Steam Plant approximately eight river miles downstream from the Alabama-Tennessee State line. The river at this point is impounded by TVA's Guntersville Dam. The Tennessee River in this area serves as a source of water supply for Bridgeport, Alabama and, during the dry season, for South Pittsburg, Tennessee, and provides cooling water for the steam plant. The area has high recreational use for fishing, boating and swimming. Commercial clamming is of considerable importance.

In addition to those elements shown, two positive occurrences of lead at 11 and 14 μg/l and a single molybdenum value of 12 μg/l were recorded. Cadmium, arsenic, beryllium, silver, nickel, cobalt, and vanadium were never detected. Seldom did the concentration of any element exceed the basin average.

TENNESSEE RIVER AT PICKWICK LANDING, TENNESSEE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	5	172	42
Boron	9	100	6	50	25
Iron	8	88.9	5	686	111
Manganese	5	55.5	0.8	4.6	2.0
Copper	9	100	3	9	6
Barium	9	100	10	28	20
Strontium	9	100	13	54	34
Aluminum	4	44.5	4	63	35
Chromium	4	44.5	4	14	8

This station is located 207 miles above the point where the Tennessee joins the Ohio River. Samples are obtained at the Pickwick Dam powerhouse approximately eight miles below the Alabama-Tennessee State line. The penstocks take water at 30 to 40 foot depths from Pickwick Reservoir. The river at, and immediately below, this station serves as a source of water supply for the town of Clifton, Tennessee and for the Tennessee River Pulp and Paper Company. Pickwick Lake provides recreation in the form of fishing, boating, and swimming. The tailwaters immediately below Pickwick Dam support a sport fishery for sauger, white bass, and catfish.

The mean zinc and iron concentrations shown in the table are influenced by a sample collected during the period October–December 1962. This 1962 sample contained zinc at 172 μg/l and iron at 686 μg/l. Excluding these two values, the mean values recorded for zinc and iron were 26 and 29 μg/l, respectively. A single lead value of 9 μg/l and two molybdenum occurrences of 3 and 4 μg/l were also recorded. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were never detected.

CLINCH RIVER ABOVE KINGSTON, TENNESSEE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	14	87.5	7	60	34
Boron	16	100	1	46	24
Iron	14	87.5	4	88	23
Manganese	12	75.0	2.0	10	5.3
Copper	16	100	4	30	15
Barium	16	100	2	47	27
Strontium	16	100	27	87	47
Molybdenum	13	81.3	5	67	31
Aluminum	7	43.7	4	85	25
Nickel	5	31.2	4	5	4
Lead	10	62.5	5	36	15
Chromium	8	50.0	2	11	5

Samples are collected at the intake of the Oak Ridge Gaseous Diffusion Plant. This station is below TVA's Melton Hill Dam (closed in the summer of 1963). Watts Bar Reservoir, another TVA impoundment, is approximately 50 miles downstream. The river at this point has reversing flows, depending on the schedule of releases from these two dams.

The principal pollution sources are the city of Oak Ridge, Tennessee, with secondary treatment, and the Oak Ridge National Laboratory. Effluents from the Laboratory are impounded by a dam on White Oak Creek before release to the Clinch River.

Analyses of 16 samples collected at this station showed trace element levels to be equal to or below basin figures. Cadmium, beryllium, silver, cobalt and vanadium were never detected; however, a single positive arsenic value of 50 μg/l was recorded in addition to those shown.

CLINCH RIVER AT CLINTON, TENNESSEE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	50	10	16	13
Boron	10	100	16	66	33
Iron	5	50	8	52	22
Manganese	5	50	1.0	11	5.2
Copper	7	70	4	17	6
Barium	10	100	19	34	27
Strontium	10	100	31	70	47
Molybdenum	5	50	10	32	20
Aluminum	3	30	3	37	24
Lead	5	50	6	37	18
Chromium	3	30	2	6	4

This is the uppermost station on the Tennessee River System, and is in the tailwaters of TVA's Norris Dam located approximately 10 river miles above the sampling point. The station lies at about the upper limit of the main arm of the impoundment created by Melton Hill Dam which was completed in the early summer of 1963. Samples are collected from the intake of the municipal water treatment plant located at State Highway 61 Bridge, 68 miles above the point where the Clinch empties into the Tennessee River. The river serves as a water supply for several small communities in the area, including Clinton and Andersonville, Tennessee.

Trace element levels were all quite low, seldom exceeding the basin averages. Cadmium, arsenic, beryllium, silver, nickel, cobalt, and vanadium were never detected.

BASIN 5

OHIO RIVER

APPENDIX E

BASIN 5 – OHIO RIVER

The Ohio River Basin contains 13 Water Quality Surveillance System stations. Seven of these are on the main stem and there is one station each on the Monongahela, Allegheny, Kanawha, Little Miami, Wabash and Cumberland Rivers.

Barium, boron and strontium were observed in over 99% of all samples; boron and strontium concentrations were below national averages. While the mean concentration for aluminum in this basin exceeded that for iron by a factor of five, iron was observed in three times as many samples.

Beryllium, nickel and cobalt were observed with a greater frequency and at higher mean concentrations than national averages. Molybdenum, manganese and lead mean concentrations were also above national levels in this basin. Zinc, cadmium, copper, silver, vanadium and chromium were observed with about the same frequency and at concentrations approximately equalling the national levels.

SUMMARY OF TRACE ELEMENTS

BASIN 5 – OHIO RIVER

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	198	81.8	3	787	81
Cadmium	7	2.9	2	11	7
Arsenic	20	8.3	26	128	66
Boron	240	99.2	1	752	67
Phosphorus	118	48.8	8	725	130
Iron	166	68.6	1	223	28
Molybdenum	68	28.1	6	473	70
Manganese	142	58.7	0.4	3230	232
Aluminum	52	21.5	7	1430	141
Beryllium	34	14.1	0.05	1.22	0.28
Copper	175	72.3	2	280	23
Silver	13	5.4	0.4	8.2	2.1
Nickel	61	25.1	2	114	31
Cobalt	24	9.9	3	48	19
Lead	45	18.6	10	140	30
Chromium	57	23.6	1	36	7
Vanadium	9	3.7	2	54	22
Barium	242	100	4	195	43
Strontium	242	100	43	520	130

ALLEGHENY RIVER AT PITTSBURGH, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, $\mu g/l$		
			Min.	Max.	Mean
Zinc	28	75.7	7	114	42
Boron	37	100	15	220	50
Iron	25	67.6	4	60	23
Manganese	22	59.5	1	3230	537
Copper	15	40.5	2	133	15
Barium	37	100	7	170	37
Strontium	37	100	44	220	95
Cadmium	3	8.1	2	11	7
Molybdenum	12	32.4	20	140	68
Beryllium	10	27.0	0.05	0.42	0.15
Nickel	15	40.5	8	86	37
Cobalt	8	21.6	3	48	18
Lead	5	13.5	10	33	18
Chromium	7	18.9	1	8	4
Arsenic	6	16.2	42	95	70

The Allegheny River begins in north-central Pennsylvania, flows into New York, re-enters Pennsylvania, and flows soutward to Pittsburgh. Oilfield brines, acid mine drainage, and mill wastes drain or are discharged to the headwaters of the Allegheny and its tributary the Kiskiminetas River.

Samples are collected from the intake of the Pittsburgh filtration plant located near the mouth of the Allegheny River. Water quality at this station is affected by discharges from industries including steel, fabricated steel products, clay, glass, paper, petroleum, food products and stone products.

Aluminum and vanadium were observed at this station on only two occasions. Silver was observed at 2 $\mu g/l$ in one sample; however, other "lesser seen elements" such as cadmium, cobalt and beryllium were observed with a much greater frequency as shown in the table. Arsenic was also frequently observed.

MONONGAHELA RIVER AT PITTSBURGH, PENNSYLVANIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	35	97.2	20	787	212
Boron	36	100	13	430	89
Iron	29	80.6	7	183	41
Manganese	30	83.3	6.6	2150	632
Copper	32	88.9	3	280	66
Barium	36	100	6	65	30
Strontium	36	100	55	520	160
Molybdenum	13	36.1	29	294	103
Aluminum	20	55.6	13	1430	300
Beryllium	23	63.9	0.07	1.22	0.34
Silver	3	8.3	1.1	4.0	2.7
Nickel	29	80.6	10	86	35
Cobalt	15	41.7	7	34	19
Lead	3	8.3	23	36	29
Chromium	6	16.7	3	36	11

The Monongahela River heads in northern West Virginia, and flows north to Pittsburgh. Both the Monongahela and its principle tributary, the Youghiogheny, are polluted by acid mine drainage so that pH values below 3.0 have been observed.

Samples are collected from the Hayes Mine Filter Plant intake about three miles from the mouth of the Monongahela River. This river is navigable for its entire length and receives large quantities of industrial wastes in its lower reaches. The industry products include steel, coal, glass and clay items and fabricated steel items. The Monongahela and Youghiogheny Rivers are interstate streams involving Maryland, West Virginia, and Pennsylvania.

As in the Allegheny, the "lesser seen elements" were observed with greater frequency, probably due to acid-mine drainage and mill wastes. A single cadmium value of 7 μg/l and an arsenic value of 86 μg/l were also recorded.

THE OHIO RIVER

The Ohio River is formed by the junction of the Monongahela and Allegheny Rivers at Pittsburgh, Pennsylvania, and flows southwesterly to its confluence with the Mississippi River at Cairo, Illinois. Surveillance stations are located at Toronto, Addison (near Gallipolis), Huntington, Cincinnati, Louisville, Evansville, and Cairo.

The average annual discharge of over 260,000 cubic feet per second makes the Ohio the largest single tributary to the Mississippi River. Navigation is maintained by a series of dams and locks throughout the Ohio and on the Monongahela and Allegheny Rivers.

The Ohio starts out as an acid stream with low pH values because of the acid mine drainage ffom the Monongahela and Allegheny Rivers. Municipal and industrial wastes from Pittsburgh and the basic steel industries and additional acid mine drainage are discharged to the upper reach of the river. By the time the Ohio has reached Addison, Ohio, it has established itself as a more typical alkaline stream.

Within the stated time period, 104 samples from the Ohio River were analyzed. Boron, barium and strontium were found in over 95% of the samples. Barium concentrations remained very constant over the length of the river, ranging from 28 μg/1 at Toronto to 41 μg/1 at Cairo. Strontium varied slightly, increasing from 105 μg/1 at Toronto at 155 μg/1 at Cincinnati, Louisville and Evansville and then receding to 103 μg/1 at Cairo.

Zinc was found in over 70% of the samples, ranging from 18 μg/1 at Cairo to 117 μg/1 at Toronto. Iron also showed a decreasing trend, dropping from 44 μg/1 at Toronto to 27 μg/1 at Cairo.

Below Cincinnati, manganese was detected in 30% of the samples with a mean of 3 μg/1. Above Cincinnati, the occurrence ranged from 44-86% with a mean of 68 μg/1 at Toronto, 36 μg/1 at Addison, and 32 μg/1 at Cincinnati. This large fluctuation in manganese is due to slug concentrations at various times.

Copper was found in 57% of the samples at Toronto and Addison with a mean of 9 μg/1. This mean value remained the same at Huntington; however, the frequency increased by over 20%. The mean copper value at Cincinnati increased by a factor of 5 to 53 μg/1 but decreased to 10 μg/1 at the three lowermost stations.

Lead and molybdenum were occasionally detected. The highest frequency (40%) for molybdenum occurred at Louisville and Evansville. The highest frequency for lead was recorded below Addison (34%); however, the mean was higher at Huntington (56 μg/1).

All elements included in the spectrographic program were detected at least once in the Ohio River.

OHIO RIVER AT TORONTO, OHIO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	7	100	43	282	117
Boron	7	100	25	170	84
Iron	6	85.7	11	102	44
Manganese	6	85.7	2.7	376	68
Copper	4	57.1	3	15	10
Barium	7	100	8	56	28
Strontium	7	100	46	210	105

This is the uppermost surveillance station on the Ohio River. It is located on the west bank approximately 19 miles downstream from the Pennsylvania-West Virginia-Ohio State line. Samples are collected from the raw water intake of the Toronto water treatment plant. The Pittsburgh–Toronto reach of the Ohio River is heavily industrialized principally with steel and fabricated steel products mills. There is some acid mine drainage in the area.

The high zinc concentrations observed at this station were most probably due to the Monongehela River. Barium levels showed no change, while strontium appeared to be an average of the levels observed in the Allegheny and the Monongahela. The "lesser seen elements" observed at the two Pittsburgh stations are either absent or below the detection limits at this station. Except for the composite of January 1 – March 31, 1966, the mean manganese concentration was 5.9 μg/1. This particular composite contained manganese at 376 μg/1. An aluminum value of 348 μg/1 was recorded in this same composite as were the highest zinc (282 μg/1) and the only positive beryllium (0.22 μg/1), nickel (19 μg/1) and vanadium (38 μg/1) values. In general, much of the trace metal pollution observed at Pittsburgh had disappeared or at least was detected at very low levels at the Toronto station.

OHIO RIVER BELOW ADDISON, OHIO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	23	71.9	8	75	26
Boron	32	100	18	752	106
Iron	17	53.1	5	113	23
Manganense	14	43.8	0.9	180	36
Copper	18	56.3	3	31	8
Barium	32	100	9	96	42
Strontium	32	100	64	280	131
Molybdenum	9	28.1	14	473	88
Aluminum	3	9.4	10	50	28
Lead	11	34.4	12	48	23
Chromium	8	25	3	9	6

Addison, Ohio is approximately 200 river miles below Toronto. This sampling point is at the intake of the Kyger Creek station of the Ohio Valley Electric Corporation, approximately four miles upstream from the mouth of the Kanawha River, and 18 miles above Gallipolis Lock and Dam. There is a complex of chemical, steel, pharmaceutical and other industries in the Wheeling, Moundsville, and Parkersburg, West Virginia, areas at distances of 80 to 170 miles upstream from the sampling point.

At Addison the mean zinc concentration had decreased to one-fourth the level observed at Toronto. Iron had also decreased. Again, except for several slugs of manganese (165 and 180 μg/1), the mean concentration of iron would have been only 13.5. Cadmium, beryllium, silver and cobalt were never observed at measurable levels. Single occurrences of arsenic (75 μg/1), nickel (16 μg/1), and vanadium (13 μg/1) were recorded. Lead and chromium, undetected at Toronto, were again at measurable levels in over 25% of the samples taken at Addison.

OHIO RIVER AT HUNTINGTON, WEST VIRGINIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	16	80	7	118	37
Boron	19	95	1	164	61
Iron	13	65	4	31	14
Manganese	13	65	1.0	32	5.8
Copper	16	80	2	35	10
Barium	20	100	4	101	37
Strontium	20	100	62	250	123
Molybdenum	4	20	10	83	48
Lead	3	15	28	91	56
Chromium	4	20	2	12	5

Approximately 45 miles downstream from Addison, samples are collected at the intake of the Huntington water treatment plant on the south bank of the Ohio River. It is approximately 38 miles below the confluence of the Kanawha and Ohio Rivers. The river in this reach is impounded by Greenup Lock and Dam approximately 36 miles downstream. Industrial discharges, particularly from the Charleston, West Virginia area on the Kanawha River, affect water quality at this station. The nearest significant municipal discharge is 34 miles upstream at Gallipolis, Ohio where primary treatment plant effluent is discharged. The cities of Ironton, Ohio, Ashland, Kentucky and Huntington, West Virginia use the Ohio River as a source of water supply.

While the frequency of lead observations was only half that at Addison, the mean concentration had more than doubled at Huntington. Boron, iron, manganese and molybdenum had all decreased, while chromium, barium and strontium remained about the same. Except for two values above 100 µg/1, the mean zinc concentration also remained unchanged. In addition to those elements shown in the table, single occurrences of nickel (33 µg/1), cobalt (36 µg/1) and vanadium (2 µg/l) were recorded. Observed on two occasions each were cadmium (2 and 9 µg/l), aluminum (7 and 35 µg/l) and silver (1.0 and 8.2 µg/l). Three positive arsenic concentrations ranging from 33 to 70 µg/l were also noted.

OHIO RIVER AT CINCINNATI, OHIO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	10	72	36
Boron	9	100	23	194	83
Iron	7	77.8	4	44	21
Manganese	7	77.8	2.9	461	73
Copper	9	100	6	117	53
Barium	9	100	10	76	41
Strontium	9	100	80	216	155

Samples are taken from the municipal water treatment plant intake located approximately one-half mile upstream from the mouth of the Little Miami River. The Corps of Engineers' Markland Lock and Dam, constructed 72 miles downstream in June 1963, increased the normal pool elevation at this station by approximately 10 feet. This section of the Ohio River supports extensive recreational use, primarily boating and water skiing, plus limited sport fishing. There are no significant sources of municipal or industrial pollution between Cincinnati and the nearest upstream surveillance station at Huntington, West Virginia, approximately 160 miles distant.

While boron showed a slight increase in concentration from that observed at Huntington, zinc, iron, barium and strontium remained at about the same levels. A single slug of manganese was again responsible for the larger mean value for manganese. Excluding this slug value of 461 µg/1, the mean would be 8.1 µg/1. In addition to the elements shown above, single positive occurrences of molybdenum (52 µg/1), aluminum (20 µg/1), nickel (2 µg/1) and lead (26 µg/1) were recorded. Cadmium, arsenic, beryllium, silver, cobalt, chromium and vanadium were never recorded.

OHIO RIVER AT LOUISVILLE, KENTUCKY

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	3	63	23
Boron	10	100	33	122	64
Iron	8	80	6	170	50
Manganese	3	30	1.8	5.7	3.5
Copper	7	70	2	27	10
Barium	10	100	22	179	58
Strontium	10	100	96	224	154
Molybdenum	4	40	9	51	34

Samples are collected at Louisville's municipal water plant intake five miles upstream from McAlpin Lock and Dam, approximately 138 miles downstream from the Cincinnati station. The Ohio River in this area sustains high recreational use for boating, water skiing and fishing. Barge traffic is heavy. The nearest significant waste discharges are the three Cincinnati primary treatment plants.

The mean zinc, barium and strontium concentrations at this station remained essentially unchanged from those observed upstream at Cincinnati. Boron and manganese decreased slightly while iron had doubled. Two occurrences each of lead (15 and 45 µg/l) and chromium (9 and 28 µg/l) were recorded as were single aluminum (17 µg/l) and nickel (26 µg/l) values. Cadmium, arsenic, beryllium, silver, cobalt and vanadium were not detected at any time.

OHIO RIVER AT EVANSVILLE, INDIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	7	77.8	10	390	82
Boron	9	100	36	172	78
Iron	7	77.8	5	81	23
Manganese	3	33.3	1.5	6.0	3.1
Copper	9	100	4	22	11
Barium	9	100	17	121	58
Strontium	9	100	91	263	157
Molybdenum	4	44.4	13	80	42

This sampling point is located at the intake of the Evansville Waterworks Department. Uniontown Lock and Dam, authorized for construction by the Corps of Engineers approximately 50 miles below this station, will raise the normal pool elevation at Evansville about three feet. There are no significant industrial discharges above this station. In the reach of river between Evansville and the next upstream surveillance station at Louisville, Kentucky, 180 miles distant, there are three major municipal discharges of primary effluent to the river.

Boron, manganese, copper, barium, strontium and molybdenum levels remained unchanged from levels observed at Louisville in this stretch of the river. Iron had decreased to the level shown at the Cincinnati station. The mean zinc concentration had increased by a factor of 3.5 due to a value of 390 μg/l observed in the July 1 – September 30, 1964 composite. Excluding this high value, the mean would be 32 μg/l. Other observations include two aluminum values of 9 and 16 μg/l, two lead values of 15 and 140 μg/l and two chromium values of 17 and 22 μg/l. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were never detected.

OHIO RIVER AT CAIRO, ILLINOIS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	19	70.4	3	65	18
Boron	26	96.3	17	100	43
Iron	15	55.6	6	107	27
Manganese	9	33.3	0.4	8.1	2.9
Copper	27	100	3	21	9
Barium	27	100	21	105	41
Strontium	27	100	59	245	103
Molybdenum	7	25.9	6	122	36
Aluminum	6	22.2	13	47	27
Lead	5	18.5	10	27	13
Chromium	8	29.0	2	13	7

Samples are taken from the Cairo municipal water treatment plant intake three miles above the Ohio's entry to the Mississippi. Between Cairo and the next upstream station at Evansville, Indiana, 190 miles away, municipal wastes from several cities, industrial wastes from refineries and canneries, and coal mine drainage are discharged to the river. All of the cities either have or soon will have built sewage treatment plants.

Zinc, boron, barium and strontium at this station all showed reductions from the mean concentrations observed at Evansville. Iron, manganese, copper and molybdenum remained unchanged. Lead and chromium were observed infrequently, while cadmium, beryllium and cobalt were never detected. Arsenic was detected on four occasions, ranging from 30 to 128 µg/l. Two positive silver values of 1.0 and 2.0 µg/l as well as single nickel (20 µg/l) and vanadium (29 µg/l) values were recorded.

KANAWHA RIVER AT WINFIELD DAM, WEST VIRGINIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	31	100	5	383	115
Boron	31	100	7	154	36
Iron	20	64.5	1	35	11
Manganese	22	71.0	0.8	115	27.4
Copper	22	71.0	5	16	8
Barium	31	100	8	195	70
Strontium	31	100	47	368	144
Aluminum	7	22.6	24	56	36
Silver	4	12.9	0.4	3.0	1.2
Nickel	9	29.0	3	23	10
Chromium	10	32.3	4	18	8
Vanadium	3	9.7	16	54	35

The Kanawha River drains the central western half of lower West Virginia and enters the Ohio at Point Pleasant, Ohio. In the Charleston area, waste discharges from a large chemical industry complex results in organic, inorganic and thermal pollution. Samples are collected at the turbine intake of Winfield Dam Power Plant approximately 25 miles below Charleston.

Zinc, manganese, barium and strontium concentrations varied considerably at this station. Cadmium, beryllium, and cobalt were never detected at measurable levels. Two instances of molybdenum at 19 and 20 µg/l and four arsenic values ranging from 26 to 70 µg/l were recorded within the time interval involved.

LITTLE MIAMI RIVER AT CINCINNATI, OHIO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	77.8	3	33	18
Boron	9	100	30	203	75
Iron	6	66.7	10	223	90
Manganese	7	77.8	1.3	11.9	6.6
Copper	6	66.7	3	14	8
Barium	9	100	33	58	47
Strontium	9	100	129	245	178
Molybdenum	6	66.7	45	144	82
Lead	3	33.3	19	68	46
Chromium	3	33.3	3	10	7

Samples are collected from State Highway 125 Bridge at Beechmont levee, two miles above the Little Miami's confluence with the Ohio. This station has a dual purpose. It monitors pollution in the Little Miami, and doubles as the surveillance system's Field Test Station for the evaluation of equipment and instrumentation.

This reach of the Little Miami River is affected by discharges of raw domestic sewage with quantities of floating solids in the Clough Creek tributary. The confluence of the two streams is downstream from the station but backwater from the Ohio occasionally forces some of the sewage upstream to the vicinity of the surveillance station.

Three high iron values of 181, 223 and 94 µg/l were responsible for the mean value of 90 µg/l which exceeds the basin level by a factor of 3. Molybdenum was observed more frequently in this stream, ranging from 45 to 144 µg/l. Copper levels were well below the basin average, while strontium ran somewhat higher. Cadmium, beryllium, silver, nickel, cobalt and vanadium were never detected. Arsenic (90 µg/l) and aluminum (18 µg/l) were observed on one occasion.

WABASH RIVER AT NEW HARMONY, INDIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	5	55.6	14	158	51
Boron	9	100	49	99	72
Iron	7	77.8	15	57	27
Manganese	3	33.3	4.6	12.0	7.1
Copper	4	44.4	6	124	39
Barium	9	100	21	51	42
Strontium	9	100	100	228	133
Molybdenum	5	55.6	60	136	84
Aluminum	3	33.3	11	95	48
Lead	4	44.4	15	57	35

The Wabash River heads in western Ohio, flows westerly across northern Indiana, turns southward, and becomes the Indiana-Illinois boundary from near Terre Haute, Indiana to its junction with the Ohio River, approximately 30 miles below Evansville, Indiana. Samples are collected at Pier C of U. S. Highway 460 bridge. This station is located on the Indiana State line approximately 52 miles above the confluence of the Ohio and Wabash Rivers.

Between New Harmony and Clinton, Indiana, the latter located about 15 miles north of Terre Haute, the Wabash River receives wastes, after primary treatment, from eight municipalities. Pollution comes also from a complex of industries including chemical, meat packing, paper, wood treatment and food processing plants.

Boron, barium and strontium were observed in all samples at concentrations approximating basin averages. Zinc and copper were infrequently found, with single values of each responsibile for higher mean values. These high values were observed in the October 1 – December 31, 1962 composite and were as follows: zinc 158 μg/l, copper 124 μg/l, nickel 114 μg/l, and lead 57 μg/l. Arsenic, beryllium, cobalt and vanadium were never detected. Cadmium at 8 μg/l and silver at 0.9 μg/l were recorded as were two chromium values of 4 and 12 μg/l.

CUMBERLAND RIVER AT CHEATHAM LOCK

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min	Max.	Mean
Zinc	5	83.3	8	29	15
Boron	6	100	20	49	35
Iron	6	100	5	44	16
Manganese	3	50	2.4	3.0	2.6
Copper	6	100	5	7	5
Barium	6	100	19	23	21
Strontium	6	100	43	68	52
Lead	4	66.7	12	40	22
Chromium	4	66.7	4	10	6

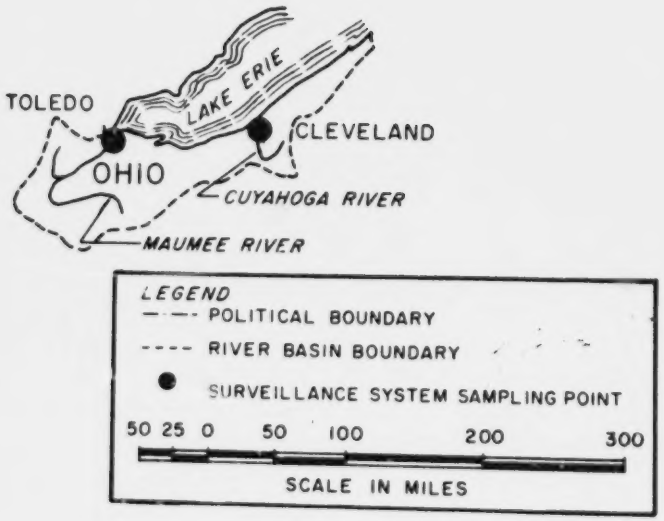
The Cumberland River heads in the Appalachian Mountains of southern Kentucky and central Tennessee, and enters the Ohio River several miles above the confluence of the Tennessee and the Ohio. The Cumberland's extensive lock, dam, and reservoir system influences its flow. Samples are collected at Cheatham Lock approximately 22 miles upstream from the Clarksville, Tennessee municipal treatment plant.

The city of Nashville discharges municipal wastes, of which about half receives secondary treatment, into the river about 20 miles upstream. Recreational use of the river includes boating and commercial and sport fishing. The river is also important for commercial clamming. Barge navigation is an additional use of the river.

Only six samples were analyzed from the Cheatham Lock station during the period July 1964 – September 30, 1967. Most of those trace elements occurring at measurable levels were below the basin as well as the national averages. Cadmium, arsenic, molybdenum, beryllium, silver, nickel, cobalt and vanadium were not detected.

BASIN 6

LAKE ERIE



APPENDIX F
BASIN 6 – LAKE ERIE

The Lake Erie Basin includes about 14,065 square miles, of which 11,660 are in northern Ohio and the remainder in Michigan, Indiana, and Pennsylvania. Three major rivers empty into Lake Erie; two of these, the Maumee and Cuyahoga, are included in the Water Quality Surveillance System.

Within the basin are a number of heavily industrialized cities, a highly developed agricultural activity based largely upon vineyards and orchards, a commercial fishery, and numerous lakeshore recreational developments.

The Maumee River at Toledo has relatively high summer temperatures, high levels of dissolved phosphate and hard water, all of which favor a rich and diverse plankton flora. In contrast, the water of the Cuyahoga River at Cleveland supports very low plankton populations. This may be due to low phosphate levels although zinc is often present at this station in concentrations known to inhibit algal growth.

The high zinc concentration in the Cuyahoga resulted in a large mean value for the Lake Erie basin. The same was true for boron and manganese. Strontium generally was observed at higher levels in the Maumee. The Lake Erie basin had a higher frequency of detection as well as a higher mean nickel value than the national averages. Again, this was a result of the nickel observed in the Cuyahoga.

SUMMARY OF TRACE ELEMENTS

BASIN 6 – LAKE ERIE

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	41	87.3	10	1183	205
Cadmium	4	8.5	6	120	50
Arsenic	2	4.3	281	336	308
Boron	47	100	28	700	210
Phosphorus	25	53.2	16	350	153
Iron	31	66.0	6	312	35
Molybdenum	13	27.7	21	108	68
Manganese	29	61.7	1.6	900	138
Aluminum	10	21.3	18	138	56
Beryllium	3	6.4	0.16	0.19	0.17
Copper	26	50.4	5	39	11
Silver	3	6.4	1.1	9.0	5.3
Nickel	25	53.2	9	130	56
Cobalt	2	4.3	20	46	33
Lead	13	27.7	16	90	39
Chromium	11	23.4	6	25	12
Vanadium	2	4.3	45	63	54
Barium	47	100	10	140	42
Strontium	47	100	82	960	260

CUYAHOGA RIVER AT CLEVELAND, OHIO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	23	100	44	1183	341
Boron	23	100	129	700	329
Iron	13	56.5	6	312	51
Manganese	16	69.5	4.5	900	244
Copper	7	30.4	6	33	14
Barium	23	100	10	140	50
Strontium	23	100	82	372	171
Cadmium	3	13.0	6	120	64
Aluminum	3	13.0	18	38	26
Nickel	17	74.0	15	130	71
Lead	4	17.4	26	88	47
Chromium	4	17.4	8	25	14

This station is approximately one mile above the point where the Cuyahoga River flows into the eastern end of Lake Erie. Samples are collected from the bridge tender's tower at Center Street Bridge. The cities of Akron and Cleveland discharge secondary sewage treatment plant effluents to the Cuyahoga. Cleveland's complex of chemical, automobile manufacture, paper and meat packing industries also discharges wastes into the river. The principal agricultural activity in the watershed is dairy farming. Lake Erie is the water supply for the City of Cleveland, whose municipal system serves a population of 1,600,000.

Zinc, boron, barium and strontium were found in all samples. Nickel was present in almost three-fourths of the samples, and iron and manganese were also frequently found. Arsenic, silver and vanadium were not observed; however, two instances each of molybdenum (24 and 30 μg/l); beryllium (0.16 and 0.16 μg/l) and cobalt (20 and 46 μg/l) were recorded.

MAUMEE RIVER AT TOLEDO, OHIO

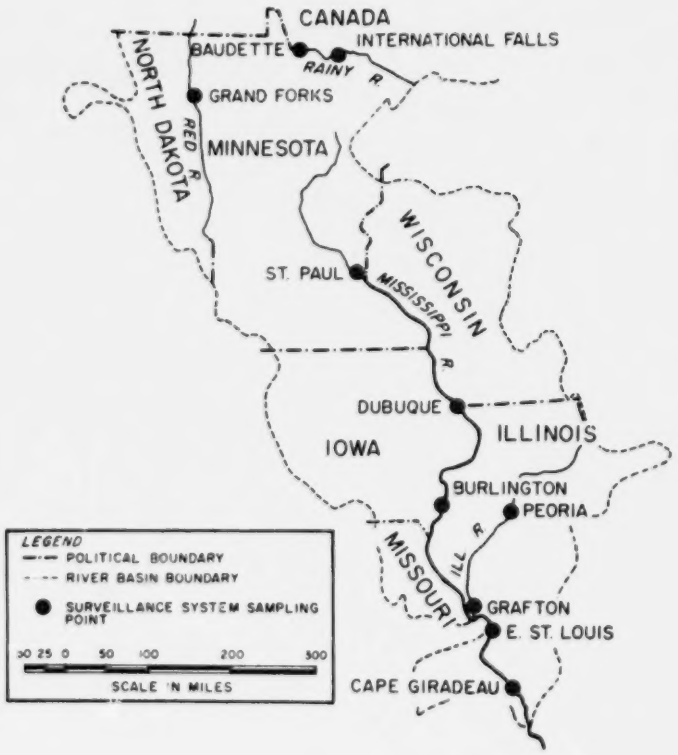
ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	18	75.0	10	96	31
Boron	24	100	28	245	95
Iron	18	75.0	9	56	23
Manganese	13	54.2	1.6	16	7.0
Copper	19	79.2	5	39	10
Barium	24	100	22	56	35
Strontium	24	100	163	960	346
Molybdenum	11	45.8	21	108	76
Aluminum	7	29.1	25	138	69
Silver	3	12.5	1.1	9.0	5.3
Nickel	8	33.3	9	58	24
Lead	9	37.5	16	90	36
Chromium	7	29.1	6	15	11

This station is located at the mouth of the Maumee River where it empties into Lake Erie. Samples are collected at the No. 2 slip of the Chesapeake and Ohio Railroad coal docks. A complex of oil refining, glass, steel, chemical, meat packing and brewery industries in the Toledo area discharges wastes directly into the Maumee River. Also, 12 major municipalities in the Maumee River basin discharge secondary effluents from their treatment plants.

Boron, barium and strontium were found in all samples, while zinc, iron and copper were found in 75%. Manganese and molybdenum were also quite regular 45 to 55% of the time. Aluminum, nickel, lead and chromium were slightly less frequent. Cobalt was never detected; however, two arsenic (281 and 336 µg/l), two vanadium (45 and 63 µg/l) and single cadmium (9 µg/l) and beryllium (0.19 µg/l) values were recorded.

BASIN 7

UPPER MISSISSIPPI



APPENDIX G

BASIN 7 – UPPER MISSISSIPPI

Portions of eight states lie within the Upper Mississippi Basin. For convenience of reference, this basin is considered to include the basins of the Red River of the North and the Rainy River which flow into Canada, in addition to the Mississippi River and its tributaries from its origin to the confluence of the Ohio River. Ten sampling points are maintained in this basin, one on the Red River, two each on the Rainy and Illinois Rivers, and five on the Mississippi.

Of those elements included in the direct-reading program, only barium and strontium occurred with a frequency of 100% within this basin. Boron was next at 98%, followed by copper and iron, each at 80%. Zinc, molybdenum and manganese were detected in 70, 69 and 62%, respectively, of all samples. Aluminum, nickel and chromium were found at measurable levels in less than 20% and cadmium, cobalt and vanadium in less than 2%. Beryllium was never detected. Molybdenum was found more often in this basin than in any other. Concentrations ranged from 4 to 360 μg/l, with a mean value of 88 μg/l.

SUMMARY OF TRACE ELEMENTS

BASIN 7 – UPPER MISSISSIPPI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	79	70.5	3	380	45
Cadmium	2	1.8	4	8	6
Arsenic	8	7.1	16	210	69
Boron	110	98.2	6	626	105
Phosphorus	87	77.7	9	1750	243
Iron	90	80.4	7	363	35
Molybdenum	77	68.8	4	360	88
Manganese	69	61.6	0.5	257	9.8
Aluminum	22	19.6	2	130	18
Beryllium	0	0	--	---	--
Copper	90	80.4	2	112	14
Silver	6	5.4	0.9	6.0	3.4
Nickel	17	15.2	1	42	15
Cobalt	1	0.9	--	---	18
Lead	27	24.1	5	119	33
Chromium	20	17.9	1	20	7
Vanadium	1	0.9	--	---	20
Barium	112	100	6	110	39
Strontium	112	100	7	310	105

RED RIVER (NORTH) AT GRAND FORKS, NORTH DAKOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	80	13	50	37
Boron	9	90	58	190	114
Iron	7	70	10	45	22
Manganese	7	70	6.8	20	11.8
Copper	5	50	11	20	13
Barium	10	10	24	80	61
Strontium	10	10	113	192	155
Molybdenum	9	90	63	360	210
Lead	4	40	21	100	52

The Red River of the North is formed at Wahpeton, North Dakota, by the junction of the Bois des Sioux and Otter Tail Rivers, and flows north into Canada where it discharges into Lake Winnipeg. The United States portion of the drainage basin covers about 34,300 square miles. The Red River is used for municipal water supplies and waste disposal. Samples are collected from the intake of the Grand Forks municipal water treatment plant. The river is shallow and slow moving, with considerable peat bog drainage upstream from the station.

Fargo, North Dakota, approximately 80 miles upstream, discharges primary sewage treatment plant effluent. Also, industrial wastes are discharged to the Red River of the North from sugar beet and potato processing plants. Agricultural activity in the watershed consists primarily of small grain crops, potatoes and livestock.

Molybdenum occurred at this station with the greatest frequency of detection of any station in the nation. The mean concentration was four times as high as national levels and almost three times the basin level. Zinc, iron, manganese and copper were usually all quite low. Arsenic, beryllium, nickel, cobalt and chromium were never detected. Single observations of cadmium (4 µg/l) and aluminum (32 µg/l), as well as two of silver (2.4 and 3.0 µg/l) were recorded.

RAINY RIVER AT INTERNATIONAL FALLS, MINNESOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	10	100	22	135	84
Boron	10	100	9	34	15
Iron	10	100	8	63	29
Manganese	8	80	0.5	2.2	1.0
Copper	9	90	5	20	11
Barium	10	100	6	27	14
Strontium	10	100	7	21	14
Molybdenum	5	50	4	11	7
Aluminum	7	70	3	23	11
Nickel	3	30	1	3	2
Lead	4	40	5	16	9
Chromium	5	50	1	5	2

The Rainy River flows a distance of approximately 75 miles from Rainy Lake to Lake-of-the-Woods, and forms the international border between Ontario and Minnesota. The International Falls station is located a short distance downstream from the outlet of Rainy Lake. Samples are collected at the pump house intake of the Minnesota and Ontario Paper Company. This plant also provides municipal water supplies to the city of International Falls. The river is little used for recreation from International Falls to Baudette, Minnesota, the next downstream sampling station.

Boron concentrations at this station were considerably below basin and national averages. Molybdenum was also quite low. Cadmium, beryllium, silver, cobalt and vanadium were never detected. Arsenic was found on two occasions at 16 and 20 μg/l. Figures for other elements are given in the table.

RAINY RIVER AT BAUDETTE, MINNESOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	100	19	380	96
Boron	10	100	6	626	80
Iron	10	100	28	118	51
Manganese	9	90	0.6	257	30
Copper	10	100	7	112	23
Barium	10	100	8	75	21
Strontium	10	100	12	95	30
Molybdenum	6	60	6	57	25
Aluminum	7	70	2	33	12
Nickel	4	40	2	42	13
Lead	3	30	5	15	11
Chromium	4	40	1	20	7

Samples at this station are collected from the intake of the Baudette municipal power plant. The Rainy River forms the boundary between central Minnesota and Ontario, and the station is approximately 19 miles above the point where Rainy River turns north and empties into Lake-of-the-Woods. Both the river and the lake sustain considerable recreational fishing and boating in the vicinity of this station. Pulp and paper mill wastes and treated municipal wastes are discharged to the river in the International Falls-Fort Frances area, approximately 75 miles upstream. Peat bog drainage from tributaries causes high color readings at this station.

All elements listed above showed increases over those observed at International Falls. The boron concentration of the April 1 – July 30, 1967 composite results in an unusually high mean value of 80 µg/l. Zinc, boron, iron, copper, barium and strontium were observed in all samples; cadmium, beryllium, cobalt and vanadium were never detected. Silver was detected once only at 0.9 µg/l and arsenic three times at 19, 24 and 46 µg/l during the period of record.

ILLINOIS RIVER AT PEORIA, ILLINOIS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	15	55.6	10	66	31
Boron	27	100	67	320	192
Iron	17	63.0	8	41	21
Manganese	14	51.9	0.8	26	9.1
Copper	19	70.4	4	44	14
Barium	27	100	9	55	30
Strontium	27	100	97	310	178
Molybdenum	17	63.0	40	230	110
Nickel	9	33.3	4	40	20
Lead	6	22.2	20	53	29
Phosphorus	25	92.6	110	1026	492

The Illinois River basin covers 26,800 square miles, mostly in Illinois. The entire river is navigable so that water transportation is possible between the Great Lakes and the Gulf of Mexico. The Illinois River joins the Mississippi River near Grafton, Ill. The terrain ranges from rolling to flat and the soil type is glacial drift.

This station is located approximately halfway between Chicago and the point where the Illinois River empties into the Mississippi River. Samples are taken from the Peoria municipal water plant intake. Municipal and industrial discharges from the Chicago metropolitan area are diverted, with dilution water from Lake Michigan, through the Chicago Sanitary and Ship Canal System to the Illinois River. Thus, a major portion of flow in the upper reach of the Illinois River is secondary sewage treatment plant effluent from Chicago. The waste loadings on this river are reflected in phosphorus concentrations which are among the highest observed throughout the surveillance system, ranging from 0.1 to 1 mg/l.

A total of 27 samples from this station were analyzed. Mean values for boron and molybdenum exceeded both basin and national levels; zinc, iron and manganese concentrations generally were quite low. Aluminum, cadmium, silver, cobalt and vanadium were each observed on only one occasion. Beryllium was never detected at this station; however, three arsenic observations of 60, 160 and 210 µg/l were recorded.

ILLINOIS RIVER NEAR GRAFTON, ILLINOIS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	62.5	16	77	37
Boron	8	100	98	380	190
Iron	6	75.0	20	61	34
Manganese	4	50.0	5.0	12	8.9
Copper	5	62.5	6	14	10
Barium	8	100	23	68	51
Strontium	8	100	82	193	133
Molybdenum	5	62.5	38	242	117
Phosphorous	8	100	67	1750	431

The surveillance system station at this site is seven miles above the confluence of the Illinois with the Mississippi River. Samples are collected at the intake of Pere Marquette State Park pump house.

Concentration ranges observed upstream at Peoria remain fairly constant and even at this distance still reflect municipal discharges from the metropolitan Chicago Area. While the mean value for phosphorus at Grafton had decreased slightly from that observed at Peoria, the maximum observed value was over 1½ times greater. Only two lead observations (21 and 50 µg/l) and singles for chromium (11 µg/l) and aluminum (130 µg/l) occurred at this station, in addition to elements tabulated above. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium, which were observed on occasion at Peoria, were never detected at Grafton.

THE MISSISSIPPI RIVER

The Mississippi River heads in Lake Itasca in northeast Minnesota and flows generally southeastward. The river is navigable from the Minneapolis-St. Paul area to New Orleans, a distance of approximately 1800 miles. The principal tributary to the Mississippi in this basin is the Missouri River at St. Louis.

Five stations in this basin are located on the Mississippi at Lock and Dam No. 3, below St. Paul, Minnesota; at Dubuque, Iowa; Burlington, Iowa; East St. Louis; and Cape Girardeau, Missouri, involving about 800 river miles.

Forty-seven samples were collected from these five Upper Mississippi River stations within the time span involved. Barium and strontium were present in all. Phosphorus was detected at the three upper stations in more than 55% of the samples at a mean concentration of 93 μg/l. The two stations below the confluence of the Illinois River showed a slight increase in frequency with a mean phosphorus value of 130 μg/l.

The mean zinc, manganese and molybdenum levels remained quite constant throughout this stretch of the river. Iron started out with a mean value of 88 μg/l but decreased over the first 200 miles to approximately one-third this value and then remained constant over the remaining 530 miles. Occasional low levels of lead and chromium were observed; however, aluminum was seldom detected. Cadmium, arsenic, beryllium, cobalt and vanadium were never detected in this stretch of the Mississippi River.

MISSISSIPPI RIVER LOCK AND DAM NO. 3 BELOW ST. PAUL, MINNESOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	77.8	5	78	27
Boron	9	100	40	220	79
Iron	8	88.9	7	363	88
Manganese	7	77.8	1.0	10.4	5.1
Copper	9	100	2	22	11
Barium	9	100	36	51	41
Strontium	9	100	59	100	72
Molybdenum	7	77.8	31	124	69
Lead	3	33.3	12	78	38
Phosphorus	7	77.8	41	224	104

This station is on the Minnesota-Wisconsin border approximately 40 miles downstream from the Minneapolis-St. Paul area. There are no reported sources of industrial pollution in the immediate vicinity; however, the Minneapolis-St. Paul area discharges treated wastes into the Mississippi River above this station. Agricultural activity in the watershed consists mainly of dairying and general farming.

Except for a high boron value and occasional high iron and molybdenum levels, trace element concentrations were all quite low, showing very little variation. In addition to those elements tabulated, two chromium values of 9 and 18 µg/l and single nickel and aluminum values of 16 and 10 µg/l, respectively, were recorded. Cadmium, arsenic, beryllium, silver, cobalt and vanadium were never detected.

MISSISSIPPI RIVER AT DUBUQUE, IOWA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	90	9	51	23
Boron	10	100	23	68	37
Iron	9	90	9	87	33
Manganese	5	50	1.8	11	5.1
Copper	10	100	9	20	13
Barium	10	100	27	45	36
Strontium	10	100	34	62	45
Molybdenum	8	80	21	160	60
Phosphorus	7	70	38	230	83

This station is located on the west side of the Mississippi River near the Iowa-Illinois-Wisconsin borders, approximately 200 miles below Lock and Dam No. 3. Samples are collected at the Corps of Engineers Lock and Dam No. 11. There are no known sources of significant municipal or industrial pollution in the vicinity. There is considerable barge traffic on the river. The city of Dubuque uses Mississippi River water only as an emergency source of supply.

Except for a molybdenum value of 160 µg/l, concentrations of all elements were quite low. Aluminum was detected on two occasions at 9 and 25 µg/l and chromium once at 11 µg/l. Cadmium, arsenic, beryllium, silver, nickel, cobalt, lead and vanadium were never observed at measurable concentrations.

MISSISSIPPI RIVER AT BURLINGTON, IOWA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	66.7	7	140	37
Boron	9	100	23	125	.51
Iron	9	100	7	116	25
Manganese	5	55.6	2.2	7.8	4.3
Copper	9	100	13	26	21
Barium	9	100	29	56	42
Strontium	9	100	36	58	50
Molybdenum	5	55.6	24	130	68
Phosphorus	5	55.6	38	182	91

The surveillance system station at Burlington, Iowa is about 35 miles above the Missouri State line. Samples are taken from the municipal water plant intake, 180 miles below the Dubuque, Iowa station. Several upstream communities within 100 miles of this station discharge both treated and raw wastes into the river.

The trace element concentration ranges showed more spread at this station; however, mean values remained about the same as upstream. While lead and chromium were each observed on one occasion at 48 and 6 µg/l, respectively, cadmium, arsenic, aluminum, beryllium, silver, nickel, cobalt and vanadium were never detected.

MISSISSIPPI RIVER AT EAST ST. LOUIS, ILLINOIS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	40	10	90	35
Boron	10	100	36	143	75
Iron	7	70	7	84	31
Manganese	5	50	1.0	11.2	5.7
Copper	7	70	3	13	8
Barium	10	100	29	67	51
Strontium	10	100	65	147	94
Molybdenum	9	90	12	112	70
Phosphorus	8	80	18	350	132

Another 200 miles downstream, samples are collected on the east bank of the Mississippi River at the intake of the East St. Louis Water Company which is approximately 20 river miles above the filter plant. There is considerable domestic and industrial use of the Mississippi River water in this area. Most of the major cities and towns, including Alton, Grafton, and Quincy, Illinois discharge treated wastes into the river. A complex of chemical, steel, petroleum and meat packing industries at Alton, Hartford, Monsanto, National City, Wood River and Roxana, Illinois discharge wastes of unknown quantity and strength into the river.

The frequency of zinc, copper and iron observations had decreased at this station from that observed at Burlington; however, the mean concentrations remained about the same. Strontium exhibited a greater range of values and also showed a higher mean concentration. In addition to those elements shown above, chromium at 8 and 14 µg/l, lead at 12 µg/l and aluminum at 13 µg/l were recorded. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were never detected.

MISSISSIPPI RIVER AT CAPE GIRARDEAU, MISSOURI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	3	35	21
Boron	8	88.9	47	176	80
Iron	7	77.8	16	52	33
Manganese	5	55.6	1.7	12	7.1
Copper	7	77.8	5	11	8
Barium	9	100	32	110	71
Strontium	9	100	100	256	154
Molybdenum	6	66.7	13	128	59
Lead	3	33.3	16	119	70
Phosphorus	5	55.6	26	283	131

This station located farthest downstream of the five in this basin, is about 145 river miles below East St. Louis. Samples are taken at the Missouri Utilities Company plant. Most of the analyses are made on waters from the Cape Girardeau municipal water plant intake located approximately 53 miles upstream from the Ohio River.

Except for increased mean levels of barium and strontium, concentrations of those elements listed above showed little change from the East St. Louis station. The frequency of detection for boron and molybdenum had decreased slightly. Lead which was missing in upstream station samples appeared with a frequency of 33%. Chromium and silver were each detected twice at 9 and 17 µg/l, and 4.5 and 6.0 µg/l, respectively. Aluminum at 15 µg/l was also observed but cadmium, arsenic, beryllium, nickel, cobalt and vanadium were never detected.

BASIN 8

WESTERN GREAT LAKES

APPENDIX H

BASIN 8 – WESTERN GREAT LAKES

The Western Great Lakes Basin, for purposes of this document, includes that portion of the United States that drains to Lakes Michigan, Huron and Superior. Three surveillance stations in the basin are located along lake shorelines at Gary, Indiana, Milwaukee, Wisconsin and Duluth, Minnesota. The remaining three stations are located on waterways between the lakes. These include the Detroit River at Detroit, Michigan, the St. Clair River at Port Huron, Michigan and the St. Mary's River at Sault Ste Marie, Michigan. The surveillance stations are located at water treatment plant intakes.

Surface streams in the area are fed largely by ground water and runoff from natural lakes. Glacial drift, consisting mostly of sands and loams, covers the region. The basin economy is based largely upon iron and copper mining, steel and automobile manufacturing, and recreation.

Lake pollution is a local problem in many areas. Before 1900, the polluted Chicago River flowed into Lake Michigan, causing severe public health problems. Since then, lake waters have been diverted through the 28-mile Chicago Sanitary and Ship Canal to the Illinois River. Average annual flows are limited to 1,500 cubic feet per second.

Samples analyzed from this basin totaled 66 in the period involved. In only five instances did an individual element exceed a concentration of 100 μg/l. The highest of these was a zinc value of 406 μg/l in the St. Mary's River. However, the mean zinc value of 24 μg/l is the second lowest of any basin. In addition, boron, copper and manganese are found at their lowest levels within this basin.

SUMMARY OF TRACE ELEMENTS

BASIN 8 – WESTERN GREAT LAKES

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	60	90.9	2	406	24
Cadmium	2	3.0	3	8	5
Arsenic	3	4.5	13	83	37
Boron	66	100	2	49	19
Phosphorus	32	48.5	5	104	31
Iron	52	78.8	1	168	22
Molybdenum	34	51.5	4	129	28
Manganese	37	56.1	0.3	7.4	2.3
Aluminum	28	42.4	1	71	17
Beryllium	1	1.5	---	---	0.05
Copper	64	97.0	1	34	7
Silver	6	9.1	0.1	3.8	1.4
Nickel	6	9.1	2	28	10
Cobalt	2	3.0	2	21	11
Lead	27	40.9	3	55	14
Chromium	19	28.8	1	20	6
Vanadium	0	0	---	---	---
Barium	66	100	5	41	15
Strontium	66	100	9	108	44

ST. CLAIR RIVER AT PORT HURON, MICHIGAN

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	90	4	20	12
Boron	10	100	12	39	20
Iron	9	90	3	53	16
Manganese	6	60	0.9	6.3	3.0
Copper	10	100	4	20	10
Barium	10	100	10	20	15
Strontium	10	100	42	77	63
Molybdenum	7	70	4	49	19
Aluminum	4	40	3	65	24
Lead	4	40	6	28	14
Chromium	3	30	4	8	5

The St. Clair River flows from Lake Huron to Lake St. Clair thence to Lake Erie via the Detroit River. Samples are collected at the Port Huron municipal water plant intake. This station is located at the beginning of the St. Clair River just above the mouth of the Black River.

Boron, copper, barium and strontium occurred with a frequency of 100%, but were all quite low in concentration. In addition to those elements shown in the table, a single occurrence of silver at 2.1 µg/l was recorded. Cadmium, arsenic, beryllium, nickel, cobalt, and vanadium were never detected.

DETROIT RIVER AT DETROIT, MICHIGAN

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	6	69	24
Boron	9	100	10	39	23
Iron	8	88.9	4	62	23
Manganese	7	77.8	0.5	6.8	3.0
Copper	9	100	6	13	8
Barium	9	100	9	22	14
Strontium	9	100	45	90	69
Molybdenum	6	66.7	15	47	28
Aluminum	3	33.3	5	68	29
Lead	5	55.6	5	53	21
Chromium	4	44.4	5	13	8

The Detroit River connects Lakes St. Clair and Erie. The sampling point is a short distance from Lake St. Clair. Samples are collected from the Detroit municipal water plant intake at Water Works Park. The data reflect the quality of the Detroit River water before it has received wastes from downstream municipalities and the complex of automotive, chemical, cement and metal working industries.

While the trace element levels at this station were all quite low, all elements included in the direct-reader program, except arsenic and vanadium, were detected at least once. In addition to the elements listed above, two cadmium (3 and 8 µg/l), one beryllium (0.05 µg/l), two silver (1.0 and 3.8 µg/l), two nickel (5 and 20 µg/l) and one cobalt (21 µg/l) were recorded.

LAKE SUPERIOR AT DULUTH, MINNESOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	90	4	17	9
Boron	10	100	7	36	17
Iron	10	100	2	83	23
Manganese	4	40	0.3	2.6	1.2
Copper	10	100	3	6	3
Barium	10	100	8	22	14
Strontium	10	100	12	27	16
Molybdenum	3	30	5	20	12
Aluminum	5	50	!	26	11
Chromium	4	40	2	20	9

Samples are taken from the Duluth municipal water intake which extends 1500 feet from shore. The plant serves an estimated 110,000 people. The city of Duluth discharges chlorinated primary effluent to the St. Louis River which subsequently empties into Lake Superior.

Due to the low dissolved solids content of water samples taken at this station, the detection limits are quite low. Therefore, many elements are detected at this station that would go undetected in other waters. In addition to elements listed in the table, the following were recorded: arsenic (83 µg/l), silver (0.2 and 0.1 µg/l), nickel (2 µg/l) and lead (7 and 20 µg/l). Cadmium, beryllium, cobalt and vanadium were never detected.

LAKE MICHIGAN AT MILWAUKEE, WISCONSIN

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	5	23	13
Boron	10	100	13	49	25
Iron	6	60	7	37	20
Manganese	4	40	0.3	7.4	2.7
Copper	9	90	2	34	13
Barium	10	100	10	26	18
Strontium	10	100	38	108	64
Molybdenum	6	60	11	129	54
Lead	3	30	7	20	13

This sampling point is in Lake Michigan at the intake of the Milwaukee water purification plant. The principal industries which may affect water quality are brewing and meat packing. The city discharges secondary treatment plant effluent into the lake. Milwaukee's port facilities are capable of handling ocean going vessels which enter the Great Lakes through the St. Lawrence Seaway.

The ten composite samples analyzed at this station all contained boron, barium and strontium at relatively low levels. Other elements occurred with lesser frequency, again at low levels. Lead was observed in three samples, the highest concentration, however, being only 20 µg/l. In addition to those elements shown, two aluminum (28 and 71 µg/l), two chromium (2 and 4 µg/l) and a single silver concentration (1.6 µg/l) were observed. Cadmium, arsenic, beryllium, nickel, cobalt and vanadium were never detected.

LAKE MICHIGAN AT GARY, INDIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	100	10	55	25
Boron	9	100	16	43	29
Iron	4	44.4	4	114	49
Manganese	6	66.7	0.7	5.5	2.4
Copper	8	88.9	2	7	4
Barium	9	100	14	41	21
Strontium	9	100	53	77	67
Molybdenum	7	77.8	13	73	35
Aluminum	4	44.4	3	58	21
Lead	3	33.3	13	55	34
Chromium	3	33.3	5	19	10

Samples are collected from the Gary municipal water treatment plant intake which extends 6,000 feet into Lake Michigan into water 35 feet deep. This plant serves an estimated 200,000 people. Lake and Porter Counties, Indiana discharge treated and untreated wastes into the Calumet River. Except during periods of high runoff, most of these wastes are diverted to the Illinois River. A complex of food processing, chemical, petroleum refining, paper and metal industries discharges effluents to Lake Michigan in this area.

Analyses of nine samples showed zinc, boron, barium and strontium present at measurable levels in all. While iron was observed in only four samples, one contained the highest iron concentration recorded within this basin. Lead and chromium were observed in three of the nine; however, cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were all either absent or below the detection limits.

ST. MARY'S RIVER AT SAULT STE. MARIE, MICHIGAN

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	18	100	2	406	41
Boron	18	100	2	28	11
Iron	15	83.3	1	168	19
Manganese	10	55.6	0.3	4.0	1.8
Copper	18	100	2	28	5
Barium	18	100	5	34	11
Strontium	18	100	9	22	14
Molybdenum	5	27.8	5	12	9
Aluminum	10	55.6	2	10	6
Nickel	3	16.7	2	28	11
Lead	10	55.6	3	12	6
Chromium	3	16.7	1	7	3

The St. Mary's River flows from Lake Superior to Lake Huron and is part of the Canada-United States boundary. Samples are collected from the Sault Ste. Marie municipal water treatment plant intake. This is near the outlet of Lake Superior, approximately two miles above the navigation locks at Sault Ste. Marie.

Note the very low mean values reported for this station. Because of the low total dissolved solids, large sample volumes can be taken for analysis. Elements which would be reported as "less than" values at most stations can be given as positive numbers due to this exceptional sensitivity. In addition to those elements listed, two arsenic values (13 and 17 µg/l) and one cobalt (2 µg/l) were observed. Cadmium, beryllium, silver, and vanadium, however, were never detected.

BASIN 9

MISSOURI RIVER

APPENDIX I

BASIN 9 – MISSOURI RIVER

Ten states and a portion of Canada make up this basin whose drainage area is 529,000 square miles.

Fifteen sampling sites are located on eight rivers of the basin. The South Platte, North Platte, Platte, Big Sioux, Yellowstone, Big Horn and Kansas Rivers have one each, and eight stations are located on the Missouri River.

With the exception of boron, barium and strontium, the frequency of detection of the trace elements was below national levels. Cadmium was never detected within this basin. Arsenic, beryllium, nickel, cobalt, vanadium, silver, lead and chromium were found in less than 5% of all samples.

SUMMARY OF TRACE ELEMENTS

BASIN 9 – MISSOURI RIVER

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	78	53.0	4	572	39
Cadmium	0	0	---	---	---
Arsenic	3	2.0	106	150	123
Boron	143	97.3	48	600	154
Phosphorus	58	39.5	23	5040	353
Iron	97	66.0	3	248	37
Molybdenum	47	32.0	8	354	83
Manganese	60	40.8	1.0	414	13.8
Aluminum	17	11.6	10	2760	213
Beryllium	3	2.0	0.01	0.56	0.23
Copper	73	49.7	3	133	17
Silver	6	4.1	0.8	1.5	1.2
Nickel	3	2.0	1	10	5
Cobalt	1	0.7	8	8	8
Lead	5	3.4	23	57	39
Chromium	7	4.8	9	27	17
Vanadium	2	1.4	158	184	171
Barium	144	98.0	8	192	63
Strontium	146	99.3	81	1000	342

BIG HORN RIVER AT HARDIN, MONTANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	60	4	46	19
Boron	10	100	79	600	196
Iron	6	60	6	56	27
Manganese	4	40	1.4	20	8.2
Copper	3	30	4	21	9
Barium	10	100	28	76	46
Strontium	10	100	290	780	492
Molybdenum	5	50	47	238	109

The Big Horn River is formed at Riverton in west central Wyoming by the junction of Buffalo Creek and the Wind River. It flows north between the Absaroka and Big Horn Mountains and enters Montana where it joins the Yellowstone River near Custer.

The Water Quality Surveillance System station at Hardin is located 60 miles below the Wyoming-Montana State line. Samples are taken at the municipal water treatement plant intake.

In addition to those elements listed, aluminum occurred in two samples at concentrations of 12 and 70 µg/l. Cadmium, arsenic, beryllium, silver, nickel, cobalt, lead and chromium were never detected. Vanadium was observed in one sample at a level of 158 µg/l.

YELLOWSTONE RIVER NEAR SIDNEY, MONTANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	100	6	116	57
Boron	8	100	108	391	222
Iron	6	75	12	132	40
Manganese	4	50	3.3	414	108
Copper	6	75	3	16	9
Barium	8	100	22	57	39
Strontium	8	100	81	540	278

The Yellowstone River heads in the Absaroka Mountains of northwestern Wyoming. The river flows through Yellowstone National Park into Montana and then northeasterly to join the Missouri River just beyond the North Dakota State line.

The Sidney station of the surveillance system is about five miles above the Montana-North Dakota State line, and approximately 25 miles above the junction of the Yellowstone River with the Missouri River. Samples are taken from the intake of the Lewis and Clark station of the Montana-Dakota Utilities Company.

Only seven metals – boron, barium, strontium, zinc, iron, manganese and copper – were found in measurable concentrations with any degree of regularity. Cadmium, arsenic, silver, nickel, cobalt, chromium and lead were never detected; single occurrences of aluminum (2.8 mg/l), beryllium (0.56 µg/l) and lead (57 µg/l) were recorded.

BIG SIOUX RIVER BELOW SIOUX FALLS, SOUTH DAKOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	6	61	21
Boron	9	100	76	355	180
Iron	5	55.6	13	45	25
Manganese	3	33.3	7.0	8.0	7.6
Copper	–	---	---	---	---
Barium	9	100	23	89	59
Strontium	9	100	129	346	229

The Big Sioux River flows almost due south from its headwaters in northeastern South Dakota to its confluence with the Missouri River at Sioux City, Iowa. Its overall length is 420 miles. Samples are collected from the first county road bridge east of U. S. Highway 229 and south of Sioux Falls. No municipal water supplies are taken from the Big Sioux River. The city of Sioux Falls discharges secondary sewage treatment plant effluent and the "Pathfinder" atomic power plant, which began operation in June 1962, discharges its wastewater to this river.

Extremely high levels of phosphorus, reflecting the upstream sewage discharges, were recorded at this station ranging from 66 to over 5000 µg/l. In addition to boron, barium and strontium, which were found in all samples, only zinc, iron and manganese occurred with any degree of regularity, and then at low levels. Cadmium, arsenic, aluminum, beryllium, copper, silver, nickel, lead and vanadium were never detected. Two occurrences of molybdenum at 92 and 234 µg/l, and a single chromium of 27 µg/l were recorded.

KANSAS RIVER AT DESOTO, KANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	8	40	26
Boron	9	100	48	340	105
Iron	6	66.7	15	46	25
Manganese	3	33.3	2.0	14	9.3
Copper	4	44.4	7	16	10
Barium	9	100	28	192	92
Strontium	9	100	195	655	369
Aluminum	3	33.3	48	150	95

The Kansas River is formed by the confluence of the Smoky Hill and Republican Rivers in central Kansas. The river then flows almost due east to its confluence with the Missouri River at Kansas City. Samples are collected at the intake of the Sunflower Ordinance Works, Hercules Powder Company. Twenty miles upstream, Lawrence, Kansas discharges primary treatment plant effluent while Topeka, Kansas, 52 miles upstream, discharges secondary effluent. Lawrence uses the river for a portion of its municipal supply.

Agriculture is the principal economic activity of the basin, with diversified crops being grown. Industrial wastes have an important effect upon the lower reach of the river. There are numerous irrigation diversions above the DeSoto station.

Two molybdenum values (50 and 51 µg/l) as well as single occurrences of aluminum (10 µg/l), silver (15 µg/l), nickel (5 µg/l), cobalt (8 µg/l) and lead (25 µg/l) were recorded. Cadmium, arsenic, beryllium, chromium and vanadium were never observed at measurable levels.

1.0

PLATTE RIVER ABOVE PLATTSMOUTH, NEBRASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	18	56	31
Boron	9	100	54	200	103
Iron	8	88.9	22	68	37
Manganese	3	33.3	2.3	12	6.3
Copper	4	44.4	3	22	10
Barium	9	100	39	188	107
Strontium	9	100	150	329	252
Aluminum	3	33.3	12	106	44

The Platte River is formed by the junction of the North Platte and South Platte Rivers at North Platte, Nebraska. This river then flows across the middle of Nebraska to join the Missouri River below Omaha. The principal use of the Platte River is irrigation.

The Plattsmouth station is located two miles above the confluence of the Platte River with the Missouri River. Samples are collected at U. S. Highway 73 bridge. The river bisects the entire State and receives wastes from almost every community along the way. These discharges range from raw sewage to secondary effluent. The lower Platte River valley supports a diversified agricultural economy. No Nebraska communities use the Platte River for water supply.

In addition to those elements listed in the table, single positive occurrences of silver (1.2 µg/l), arsenic (106 µg/l), lead (45 µg/l) and chromiun (18 µg/l) were recorded. Cadmium, molybdenum, beryllium, nickel, cobalt and vanadium were not detected.

NORTH PLATTE RIVER ABOVE HENRY, NEBRASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	60	7	572	131
Boron	9	90	82	291	131
Iron	6	60	7	50	24
Manganese	5	50	1.1	16	7.8
Copper	4	40	6	20	11
Barium	10	100	19	102	62
Strontium	10	100	220	462	325
Molybdenum	3	30	13	106	60

The North Platte River flows from northern Colorado into Wyoming where it makes a wide arc to the east and enters Nebraska. This stream has a large number of reservoirs for irrigation and sustains fish and wildlife in important numbers.

This Henry, Nebraska station is located downstream from the Nebraska-Wyoming State line. Samples are taken from State Highway No. 86. Irrigated agriculture is the principal economic activity and sugar beets are the leading crop. Several beet sugar refineries in this area discharge partially treated wastes into the river. These wastes and irrigation return flows have created a pollution problem in this river.

One occurrence of nickel (1 µg/l) was reported at this station in addition to elements listed above. Cadmium, arsenic, beryllium, aluminum, silver, cobalt, lead, chromium and vanadium were never detected.

SOUTH PLATTE RIVER AT JULESBURG, COLORADO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	40	10	84	57
Boron	9	90	110	519	248
Iron	3	30	31	47	41
Manganese	4	40	9.2	31	16.8
Barium	10	100	15	92	51
Strontium	10	100	525	1000	741
Molybdenum	3	30	15	354	181

The South Platte River originates at South Park in central Colorado, flows east from the mountains a few miles south of Denver, and then bends northerly toward Denver. Denver obtains a portion of its water supply from, and discharges all of its wastes into, this river. Leaving Denver, the South Platte flows north and east to North Platte, Nebraska, where it joins the North Platte River. The South Platte is extensively utilized for irrigation, particularly for sugar beets, the principal crop of the basin.

Samples are taken at the Julesburg sewage treatment plant one mile east of the city. This station is located two miles above the Colorado-Nebraska State line. Return flows from the extensive irrigated agriculture system are responsible for relatively high concentrations of dissolved salts in the river waters.

In addition to those elements listed in the above table, a single positive occurrence of vanadium (184 µg/l) was recorded. While vanadium was observed at many stations below 10 µg/l, it is rarely found at this high level. Two copper values of 4 and 20 µg/l were also recorded. This station had one of the lowest percent detection figures for copper, (20%). Cadmium, arsenic, aluminum, beryllium, silver, nickel, cobalt and lead were never detected.

THE MISSOURI RIVER

The Missouri River is formed by the junction of the Galiatin, Madison and Jefferson Rivers in southwestern Montana at the town of Three Forks and flows 2,464 miles to its confluence with the Mississippi River at St. Louis. The drainage area of 529,000 square miles covers 10 states and a portion of Canada.

The river is regulated by multipurpose dams and reservoirs on major tributaries and the main stem. Major Missouri River impoundments include Fort Peck, Garrison, Oahe, St. Randall and Gavin's Point. The principal tributaries to the main stem are the Yellowstone, Big Sioux, Platte, and Kansas Rivers. The Big Horn River is tributary to the Yellowstone.

No surveillance stations are maintained over the first 900 miles of the Missouri River; waters of the remaining 1500 miles are monitored at eight sites. These include Williston, N. D., Bismarck, N. D., Yankton, S. D., Omaha, Nebr., St. Joseph, Mo., Kansas City, Kans., Missouri City, Mo. and St. Louis, Mo.

The levels of trace metals over this distance remained quite constant as may be seen in the tables. The greatest variation occurred with iron and copper due to several unusually high values recorded during the period involved. Cadmium and vanadium were never detected in any samples from the Missouri River. Single occurrences of nickel and cobalt, two each of beryllium and arsenic, and three each of silver, lead and chromium were recorded. Aluminum was found in 10% of all samples while molybdenum was more frequent at 36%. Missouri River samples analyzed totaled 82.

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MISSOURI RIVER AT WILLISTON, NORTH DAKOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	20	56	32
Boron	10	100	87	262	146
Iron	8	80	14	99	45
Manganese	5	50	1.0	5.8	4.2
Copper	9	90	8	54	25
Barium	10	100	30	61	44
Strontium	10	100	216	432	317
Molybdenum	6	60	17	135	81

The Williston station is the extreme upstream sampling point on the Missouri River. It is located about 11 miles below the Montana-North Dakota State line, and 10 miles below the confluence of the Yellowstone River. Samples are collected at the Williston municipal water treatment plant intake. The station is in pool from Garrison Dam.

Boron, barium and strontium were observed in all samples. Copper, iron, zinc, molybdenum, and manganese were found over 50% of the time at measurable levels. In addition, single occurrences of aluminum and silver at 95 and 1.3 µg/l, respectively, were recorded. Cadmium, arsenic, beryllium, nickel, cobalt, lead, chromium and vanadium were never detected.

MISSOURI RIVER AT BISMARCK, NORTH DAKOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	40	9	42	23
Boron	9	90	91	272	170
Iron	6	60	15	179	56
Manganese	4	40	1.3	4.0	2.8
Copper	10	100	14	50	24
Barium	9	90	40	63	48
Strontium	9	90	239	409	306
Molybdenum	4	40	16	65	39

The second uppermost sampling station on the Missouri River is located at Bismarck, approximately 240 miles below Williston, North Dakota and 70 miles below Garrison Dam. Trace elements at this station showed little, if any, change either in frequency or in concentration from those observed at Williston. Single observations of arsenic (115 µg/l) and chromium (11 µg/l) were recorded; cadmium, aluminum, beryllium, silver, nickel, cobalt, lead and vanadium were never detected.

MISSOURI RIVER AT YANKTON, SOUTH DAKOTA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	50	11	48	31
Boron	10	100	98	318	147
Iron	5	50	14	61	27
Manganese	3	30	1.6	23	9.6
Copper	7	70	8	133	42
Barium	10	100	38	65	48
Strontium	10	100	245	425	324
Molybdenum	3	30	24	76	57

The Yankton, South Dakota station is located about seven miles below Gavin's Point Dam, last of the series of dams on the main stem of the Missouri. Yankton is 500 river miles below Bismarck, North Dakota. Samples are collected at the Yankton municipal water treatment plant intake. The Niobrara and White Rivers are tributary to the Missouri, flowing into Lewis and Clark Reservoir impounded by Gavin's Point Dam.

In addition to those elements shown in the table, a single silver value of 0.8 µg/l was recorded at this station. Other elements such as cadmium, aluminum, beryllium, nickel, cobalt, lead, chromium and vanadium were not detected.

MISSOURI RIVER AT OMAHA, NEBRASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	40.0	13	103	38
Boron	15	100	75	336	139
Iron	10	66.7	12	24	18
Manganese	6	40.0	2.4	16.8	6.2
Copper	3	20.0	8	17	11
Barium	14	93.3	32	140	72
Strontium	15	100	209	600	338
Molybdenum	7	46.7	14	188	75
Aluminum	3	20.0	11	13	12

Omaha, Nebraska, is approximately 180 river miles below Yankton, South Dakota. One hundred miles upstream the Big Sioux River and the Sioux Falls, Iowa municipal and industrial waste discharges enter the Missouri. Samples are collected at the Omaha municipal water treatment plant intake.

Here the frequency of detection and also the mean concentration for copper had decreased somewhat, possibly due to dilution from the Big Sioux, which is also low in copper. Barium showed a slight increase; however, there was little or no change in the other elements.

Cadmium, silver, nickel, cobalt, lead, chromium and vanadium were never detected at this station in measurable concentrations. Single observations of arsenic at 150 µg/l and beryllium at 0.01 µg/l were recorded.

MISSOURI RIVER AT ST. JOSEPH, MISSOURI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	3	30	7	32	18
Boron	10	100	78	232	126
Iron	5	50	18	60	37
Manganese	5	50	2.6	19	8.7
Copper	5	50	5	17	8
Barium	10	100	30	132	70
Strontium	10	100	244	500	314

St. Joseph is located 450 river miles above the mouth of the Missouri River. Samples are collected at the municipal water treatment plant intake. This station is approximately 180 miles downstream from Omaha, Nebraska and is affected by municipal and industrial discharges from that area. The mineral quality of waters at St. Joseph station is affected by waters from the Platte River.

Strontium, barium and boron were the only elements that appeared regularly in higher concentrations. Iron, between 18-60 µg/l, appeared occasionally, along with manganese and copper. Chromium, cadmium, silver, nickel, arsenic, cobalt and vanadium were never observed in positive concentrations. Single occurrences of molybdenum (120 µg/l), aluminum (118 µg/l), beryllium (0.12 µg/l), and lead (46 µg/l) were recorded.

MISSOURI RIVER AT KANSAS CITY, KANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	3	33.3	19	36	26
Boron	9	100	94	273	151
Iron	6	66.7	12	248	87
Manganese	3	33.3	2.8	7.0	4.6
Copper	8	88.9	4	19	11
Barium	9	100	31	164	85
Strontium	9	100	129	415	267
Molybdenum	4	44.4	33	96	57

Samples are collected at the municipal water treatment plant intake. This station monitors the Missouri River above the confluence of the Kansas River and is affected by municipal and industrial discharges from St. Joseph, Missouri and Omaha, Nebraska, located 77 and 268 miles upstream, respectively.

Two concentrations of iron at 164 and 248 µg/l were responsible for the mean being twice that observed upstream at St. Joseph. Other levels showed very little change from one station to the next. Copper showed a slight increase in frequency; however, zinc, manganese and molybdenum remained under 50%. Except for a single occurrence of aluminum at 17 µg/l, no other elements were detected at measurable levels.

MISSOURI RIVER AT MISSOURI CITY, MISSOURI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	8	43	21
Boron	9	90	72	184	110
Iron	9	90	3	106	30
Manganese	4	40	1.0	10	4.5
Copper	3	30	4	18	8
Barium	10	100	8	162	64
Strontium	10	100	120	485	272

Samples are collected at the intake of the Northwest Electric Power Cooperative.

Liberty, Missouri, the nearest upstream community, discharges sewage into a tributary nine miles above the station. The cities of Kansas City, Kansas, Kansas City, Missouri, and North Kansas City, Missouri contribute both sewage and industrial wastes about 50 miles upstream. Primary treatment plants are either in planning or under construction in upstream areas and should relieve the polluted condition which existed during the period involved.

In addition to those elements listed in the above table, single positive occurrences of silver (1.5 µg/l), nickel (5 µg/l), cobalt (8 µg/l), lead (25 µg/l) and aluminum (10 µg/l) were observed. Cadmium, arsenic, beryllium, chromium and vanadium, however, were never detected.

MISSOURI RIVER AT ST. LOUIS, MISSOURI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	50.0	12	28	19
Boron	8	100	81	480	164
Iron	8	100	8	155	42
Manganese	4	50.0	1.6	6.0	3.6
Copper	4	50.0	6	16	10
Barium	7	87.5	21	94	48
Strontium	8	100	187	360	257
Molybdenum	4	50.0	8	40	30

This terminal surveillance station on the Missouri is located 37 miles above the river's mouth. Samples for trace element analyses are collected from the intake of the city of St. Louis' Howard Bend water treatment plant at river mile 37.2.

The nearest upstream municipal and industrial waste discharges which affect this station are those from the metropolitan Kansas City area.

An unusually high boron reading of 0.48 mg/l reflects in the mean boron value which showed a 50% increase over that at Missouri City. Aluminum at 86 µg/l and lead at 23 µg/l were recorded in single samples as were two chromium values of 18 and 26 µg/l. Cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were never detected.

BASIN 10

SOUTHWEST-LOWER MISSISSIPPI

APPENDIX J

BASIN 10 – SOUTHWEST–LOWER MISSISSIPPI

The Southwest – Lower Mississippi River Basin contains 17 Water Quality Surveillance System stations situated on five rivers. Five of the stations are on the Mississippi River mainstem below the confluence of the Ohio River, five are on the Arkansas River mainstem, and four are on the mainstem of the Red River. The Verdigris and the Ouachita Rivers, tributary to the Arkansas and Red Rivers, respectively, are also sampled, as is the Atchafalaya River.

Samples analyzed in this basin during the time involved totaled 155. Barium, boron and strontium were found at measurable levels in over 98% of these samples. Iron was observed in 80% of the samples, while zinc and copper were found in approximately 63%. Aluminum, molybdenum, chromium and manganese were found in 19-35% of the samples. Arsenic, silver, nickel, cobalt, lead and vanadium were found in less than 10% of the samples; cadmium and beryllium were never detected. Mean basin values for zinc, boron, iron, aluminum, copper, barium, strontium, lead, chromium, molybdenum and silver exceeded the national levels.

SUMMARY OF TRACE ELEMENTS

BASIN 10 – SOUTHWEST–LOWER MISSISSIPPI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	97	62.6	3	1080	85
Cadmium	0	0	--	----	---
Arsenic	2	1.3	56	126	91
Boron	154	99.4	9	1020	131
Phosphorus	47	30.3	5	329	81
Iron	110	80.0	3	837	69
Molybdenum	31	20.0	11	1100	95
Manganese	54	34.8	0.6	50	9.0
Aluminum	30	19.4	7	588	68
Beryllium	0	0	--	----	---
Copper	99	63.9	2	250	19
Silver	7	4.5	1.1	9.0	4.3
Nickel	15	9.7	5	50	17
Cobalt	1	0.7	36	36	36
Lead	15	9.7	9	75	37
Chromium	31	20.0	2	90	16
Vanadium	6	3.9	4	67	25
Barium	155	100	13	262	90
Strontium	153	98.7	78	5000	540

THE ARKANSAS RIVER

The Arkansas River heads in the Rocky Mountains near Leadville, Colorado. The river flows in a southeasterly course to its confluence with the Mississippi River in southeast Arkansas. Irrigation places heavy demands on the stream waters in the semiarid and dry regions east of the mountains. Dissolved solids build up as a result of both natural and man-made pollution above Tulsa, Oklahoma, and are subsequently reduced by dilution from other streams in Arkansas. Pueblo, Colorado, is the only large community to use the Arkansas River as a municipal supply. The Verdigris River drains from eastern Kansas southward into Oklahoma and joins the Arkansas River near Muskogee, Oklahoma.

Forty-five samples from the five stations on the Arkansas River were analyzed within the time period involved. Manganese was detected in only 10 (22.2%) of these; copper occurred in 16 (35.6%). The mean zinc values varied considerably in the Arkansas River because of several high individual values. The stretch of river from Collidge, Kansas to Pendleton Ferry, Arkansas showed a decrease in the mean boron level from 675 to 64 µg/l. The mean strontium also decreased from 2400 to 350 µg/l over this same distance. The high iron levels at Collidge decreased by a factor of 6 by the time the Arkansas reached Ponca City, Oklahoma, a distance of 450 miles.

Cadmium, arsenic, beryllium, cobalt and vanadium were never observed at measurable levels in the Arkansas River; single occurrences of both silver and lead were recorded. Nickel, chromium and aluminum were found in less than 9% of the samples.

ARKANSAS RIVER AT COOLIDGE, KANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	4	40	5	256	127
Boron	9	90	240	1020	675
Iron	5	50	77	837	283
Manganese	6	60	15	50	36
Copper	2	20	5	30	17
Barium	6	60	18	60	36
Strontium	10	100	536	5000	2386
Molybdenum	4	40	200	1100	460

The Coolidge, Kansas station is located 1½ miles downstream from the Colorado-Kansas State line. Samples are taken from the south bank, 50 feet below the U. S. Geological Survey gaging station. Fifty miles upstream, John Martin Dam creates a storage reservoir for irrigation usage. At times, this reservoir has been completely drained to satisfy appropriations. The nearest pollutional sources to the Coolidge station are Holly and Lamar, Colorado; six and thirty-four miles upstream, respectively.

The Coolidge station is one of the few in the entire surveillance system where barium was not always found at measurable concentrations. Because of the high total dissolved solids present, relatively small sample aliquots were analyzed, resulting in unsatisfactory limits of detection for many elements. Single occurrences of aluminum (428 μg/l), nickel (16 μg/l) and chromium (90 μg/l) were recorded. Cadmium, arsenic, beryllium, silver, cobalt, lead and vanadium were either absent or below the detection limits.

ARKANSAS RIVER NEAR PONCA CITY, OKLAHOMA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	3	30	10	28	19
Boron	10	100	48	700	188
Iron	4	40	24	66	46
Barium	10	100	96	262	159
Strontium	10	100	540	2300	1190

This station is approximately 50 river miles downstream from the Oklahoma-Kansas State line. Samples are taken from the downstream side of old U. S. Highway 60 Bridge, east of Ponca City. No known municipal use is made of this river from Ponca City upstream to the Coolidge station. The nearest upstream city is Arkansas City, Kansas, at the State line.

The region is largely agricultural with industrialization in the Wichita, Kansas area. Hutchinson, Kansas is the site of a salt mine and some natural salt is contributed by Rattlesnake Creek. Oil fields are located in the vicinity of Great Bend, Kansas.

The Arkansas River at Ponca City showed high phosphate concentrations, averaging nearly 1 mg/l over the stated time interval, presumably from farm fertilization.

Other than elements listed in the above table, only copper at 9 µg/l and chromium at 24 µg/l were recorded. Cadmium, arsenic, manganese, molybdenum, aluminum, beryllium, silver, nickel, cobalt, lead and vanadium were never detected.

ARKANSAS RIVER NEAR FORT SMITH, ARKANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	75.0	9	350	120
Boron	7	87.5	46	169	100
Iron	5	62.5	15	77	48
Copper	5	62.5	3	20	10
Barium	8	100	83	216	131
Strontium	8	100	264	1340	585

The surveillance system station near Fort Smith, Arkansas is located at the Oklahoma-Arkansas State line. Samples are collected at the U. S. Highway 64 bridge. Between the Ponca City and Fort Smith stations, the Salt Fork of the Arkansas and the Cimarron River contribute heavy salt loadings. These are diluted by waters of the Verdigris, Grand, Illinois, and Canadian Rivers so that total dissolved solids concentrations are generally between 350 and 700 mg/l at the Fort Smith station.

The principal industry in the Ponca City-Fort Smith area is petroleum production and refining. Many of the oil fields in this area were developed prior to advancement of adequate brine disposal techniques. Consequently, these oil fields still are sources of salt loading which if flushed from evaporation ponds during the rainy season.

Cadmium, arsenic, molybdenum, beryllium, cobalt, lead and vanadium were never observed at measurable levels. However, single observations of manganese (9.0 µg/l), aluminum (20 µg/l), silver (7.0 µg/l), nickel (9 µg/l) and chromium (26 µg/l) were recorded.

ARKANSAS RIVER AT LITTLE ROCK, ARKANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	4	50.0	6	117	60
Boron	8	100	42	180	87
Iron	5	62.5	5	70	38
Copper	5	62.5	2	18	9
Barium	8	100	81	147	100
Strontium	7	87.5	210	473	344

This surveillance system station is located about midway between the Fort Smith and Pendleton Ferry stations in central Arkansas. Samples are collected at the pipe yard of the Little Rock Water Department. The influent salt which affects water quality upstream at Fort Smith has been moderated at Little Rock by the influx of waters low in mineral concentrations. The nearest community discharging wastes to the river is Morrilton, Arkansas, 57 miles upstream from Little Rock. Manganese at 6 μg/l, lead at 20 μg/l, and chromium at 14 μg/l were observed in addition to the six elements tabulated above. Cadmium, arsenic, molybdenum, aluminum, beryllium, silver, nickel, cobalt and vanadium were never detected at this station.

ARKANSAS RIVER AT PENDLETON FERRY, ARKANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	6	43	25
Boron	8	88.9	48	81	64
Iron	6	66.7	13	239	86
Manganese	2	22.2	2.0	11	6.5
Copper	3	33.3	3	7	5
Barium	9	100	76	120	99
Strontium	8	88.9	182	525	349
Chromium	3	33.3	10	29	18

This is the final surveillance system station on the Arkansas River before its confluence with the Mississippi, 44 miles downstream from Pendleton Ferry. Samples are collected from the ferry at approximately midstream. The nearest community above this station is Pine Bluff, Arkansas approximately 40 miles upstream. The Arkansas River in this area is not used for either irrigation or municipal supply.

In addition to those elements shown above, two occurrences of aluminum (20 and 34 µg/l) and a single occurrence of nickel at 5 µg/l were reported. No other trace elements were found at measurable levels.

VERDIGRIS RIVER AT NOWATA, OKLAHOMA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	2	28.6	24	32	28
Boron	7	100	9	71	51
Iron	5	71.4	14	48	26
Manganese	2	28.6	4.3	6.7	5.5
Copper	5	71.4	4	16	9
Barium	7	100	19	133	91
Strontium	7	100	247	1125	600

The Verdigris River heads in southeast Kansas and flows southward to its junction with the Arkansas River near Muskogee, Oklahoma. The Nowata station is located 20 miles downstream from the Kansas-Oklahoma State line. Samples are taken from Nowata's municipal water plant intake.

In addition to those elements listed above, two aluminum (10 and 17 µg/l), two lead (9 and 29 µg/l), two chromium (2 and 15 µg/l), and single occurrences of silver (1.1 µg/l) and vanadium (67 µg/l) were recorded. Cadmium, arsenic, molybdenum, beryllium, nickel and cobalt were never detected. Vanadium has also been observed at Norman, Oklahoma and at Nichols Hills, Oklahoma at 110 and 500 µg/l respectively. These two locations are not regular surveillance system sampling points.

RED RIVER OF THE SOUTH

The Red River heads in the high plains of the Texas Panhandle, South of Amarillo, in Palo Duro Canyon, and at several other points farther downstream, the river is degraded by rising salty ground water from several natural sources in this basin. Oil field pollution is being rapidly corrected. The Red River is subsequently diluted by the Washita River which enters Lake Texoma above Denison Dam and thereafter by several large tributaries. However, the rainfall variability and the operation of Denison Dam cause fluctuating mineral concentrations in the lower portion of this river. Only one municipality, Bossier City, La., uses the Red River as a source of supply. The Red River is confluent to the Atchaflalaya River, a distributary of the lower Mississippi in Louisiana.

Barium and strontium in the Red River of the South were observed at some of the highest levels in the national System. Concentrations for most elements varied considerably from station to station. Manganese was observed infrequently in this stream, being found in only 18% of the samples and ranging from 3 to 15 µg/l. Molybdenum, chromium, aluminum and lead occurred at measurable levels in fewer than 5% of all samples, while cadmium, arsenic, beryllium, silver, nickel, cobalt and vanadium were all either absent or below the detection limits.

RED RIVER AT DENISON, TEXAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	100	9	320	83
Boron	8	80	93	403	227
Iron	3	30	3	73	37
Copper	8	80	12	78	35
Barium	9	90	65	205	145
Strontium	8	80	480	1386	987

This uppermost station on the Red River of the South is approximately 726 miles above the mouth. Samples are collected from the penstock of Denison Dam. The Red River at this point has formed the boundary between Texas and Oklahoma for some 200 miles. There is no municipal use of the Red River above the Denison station because of the high salt concentrations from brine seeps and flood plains. Oil field practices in the past have contributed to this salt load but these sources are being eliminated by State agency enforcement actions. Almost all of the communities upstream from Denison use the Red River or some one of its tributaries as a receiving water for their municipal wastes.

Cadmium, arsenic, aluminum, beryllium, silver, nickel, cobalt, lead, chromium and vanadium were never detected. Single occurrences of molybdenum at 49 µg/l and manganese at 15 µg/l were recorded.

RED RIVER AT INDEX, ARKANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	40	3	86	32
Boron	10	100	50	197	125
Iron	7	70	17	95	42
Manganese	2	20	3.3	5.0	4.1
Copper	2	20	5	7	6
Barium	10	100	52	182	122
Strontium	10	100	268	874	613

This station is located at the point where the Red River ceases to form the Arkansas-Texas boundary and begins its flow through southwest Arkansas to Louisiana. Samples are collected from U. S. Highway 71 bridge. The Denison, Texas station is approximately 240 r. .r miles upstream from the Index, Arkansas station. Blue River, Boggy Creek and the Kiamichi River are confluent to the Red River from Oklahoma in the reach above Index and below Denison. Bois D'Ark Creek and Pecan Bayou are the principal tributaries entering from Texas. These tributaries drain an area whose rainfall averages about 40 inches per year.

Nearly all the municipalities in the Red River basin discharge wastes into the river or its tributaries. The two cities nearest to the Index station are DeKalb, Texas and New Boston, Texas at 36 and 25 miles above the station. Both operate secondary sewage treatment plants.

In addition to the seven elements tabulated above, aluminum was detected on one occasion at 80 µg/l. Cadmium, arsenic, molybdenum, beryllium, silver, nickel, cobalt, lead, chromium and vanadium were never detected.

RED RIVER AT BOSSIER CITY, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	4	1080	165
Boron	8	88.9	26	140	89
Iron	8	88.9	7	134	38
Manganese	2	22.2	3	4	3.5
Copper	7	77.8	4	21	12
Barium	9	100	68	202	119
Strontium	8	88.9	191	592	382

Samples are collected from the Bossier City municipal water treatment plant intake. This station is approximately 35 miles below the Arkansas-Louisiana State line and 175 miles below the nearest upstream station at Index, Arkansas. Bossier City is the only municipality known to draw its supply from the Red River. The variability of mineral concentrations has required this community to install a reservoir and a plan to pump from the river only when satisfactory quality prevails.

In addition to the seven elements tabulated above, two instances of chromium at 7 and 13 µg/l and one of lead at 60 µg/l were recorded. No other trace elements were observed.

RED RIVER AT ALEXANDRIA, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	2	20	29	58	43
Boron	10	100	60	200	102
Iron	7	70	18	395	88
Manganese	2	20	3.0	6.0	4.5
Copper	4	40	6	14	10
Barium	10	100	56	156	99
Strontium	10	100	200	771	444
Aluminum	3	30	13	588	207
Chromium	3	30	11	42	23

This surveillance station, approximately 190 miles below Bossier City, monitors the quality of the Red River before its entry into the Atchafalaya River system. Samples are collected from U. S. Highway 165 bridge. Organic pollution is the principal problem at this station. Bossier City, Shreveport, Pineville, and Alexandria, Louisiana discharge sewage to the Red River above this station as does Barksdale AFB at Shreveport and England AFB at Alexandria. Three miles above the Alexandria station, a Veterans Administration Hospital also discharges waste from a population of 500.

In addition to elements listed above, molybdenum was detected in one sample at 22 µg/l.

ATCHAFALAYA RIVER AT MORGAN CITY, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	83.3	15	36	23
Boron	6	100	63	141	101
Iron	4	66.7	14	84	39
Manganese	5	83.3	3.3	24	11
Copper	6	100	12	250	99
Barium	6	100	45	130	86
Strontium	6	100	124	340	205

In addition to the above tabulations, single occurrences of aluminum, silver, lead and chromium at 61, 3.6, 17 and 5 µg/l, respectively, were recorded. Cadmium and vanadium were never detected.

Zinc, iron and strontium concentrations at the Morgan City station were all lower than those observed in the Red River at Alexandria. The mean boron and barium levels remained unchanged; however, copper showed a tenfold increase.

OUACHITA RIVER AT BASTROP, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	77.8	67	924	409
Boron	9	100	34	168	100
Iron	9	100	13	800	215
Manganese	4	44.4	1.5	11	6.0
Copper	8	88.9	8	82	36
Barium	9	100	67	129	96
Strontium	8	88.9	83	774	411
Aluminum	5	55.6	14	240	78

The Ouachita River flows southward from central Arkansas and, in its lower reach, becomes the Black River. The Black River is tributary to the Red River about 30 miles downstream from Alexandria, Louisiana.

The site of the Bastrop station is approximately 14 miles downstream from the Arkansas-Louisiana State line and 215 miles above the confluence of the Ouachita with the Red River. Samples are collected from the east bank, seven miles west of Bastrop. The Ouachita River is navigable at this point and the flow is regulated by navigation locks and dams. The principal agricultural activity in this area is cotton raising. Crossett, Arkansas, site of a pulp mill, is the nearest community about 30 miles upstream.

Nickel at 17 and 50 µg/l, as well as silver, chromium and vanadium at 2.0, 17 and 12 µg/l, respectively, were recorded in addition to elements tabulated above. Cadmium, arsenic, molybdenum, beryllium, cobalt and lead were never observed at this station.

THE LOWER MISSISSIPPI RIVER

The surveillance system station at West Memphis, Arkansas, monitors inflow to the lower Mississippi River which eventually flows to the Gulf of Mexico. This portion of the Mississippi is 725 miles long. Twin stations are installed at Delta, Louisiana and Vicksburg, Mississippi on the opposite bank, to adequately monitor water quality in the presence of incomplete mixing of tributary flows from the Yazoo River at this point.

Mean levels of boron, barium and strontium observed at Cape Girardeau were slightly higher than at West Memphis. Zinc, iron and copper, however, showed slight decreases. Mean levels for all elements over this stretch of the Mississippi River remain quite constant. Except for a slight increase in zinc mean concentration at Delta, Louisiana, the high levels of strontium found in the Arkansas apparently have little effect on the Mississippi.

Molybdenum, observed quite frequently in the upper Mississippi, was also found in the lower stretch, but at slightly lower level. Mean concentrations of zinc, boron, manganese, copper and barium showed little variation from those observed in the upper Mississippi. Iron levels decreased slightly.

MISSISSIPPI RIVER AT WEST MEMPHIS, ARKANSAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	60	6	90	31
Boron	10	100	38	82	57
Iron	8	80	12	150	39
Manganese	6	60	0.6	12.6	5.0
Copper	7	70	2	25	12
Barium	10	100	13	79	41
Strontium	10	100	92	144	115
Molybdenum	6	60	14	91	45
Nickel	4	40	8	30	19
Chromium	3	30	7	40	18

This station is located on the west shore of the Mississippi River, approximately 725 miles above the mouth. Samples are collected from the floating dock of the Oklahoma-Mississippi River Products Company.

Municipal sewage is discharged within one-half mile upstream by West Memphis, Arkansas. Across the river, Memphis, Tennessee discharges sewage through four outfalls, three of them upstream from the sampling station and one downstream.

Two occurrences each of aluminum (28 and 36 µg/l), silver (1.8 and 5.8 µg/l) and lead (12 and 29 µg/l), plus a single occurrence of vanadium (15 µg/l) were recorded, in addition to the 10 elements tabulated above for this station.

MISSISSIPPI RIVER AT DELTA, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	14	264	61
Boron	10	100	33	95	56
Iron	9	90	9	94	43
Manganese	5	50	2.0	12	5.2
Copper	8	80	6	22	12
Barium	10	100	22	81	56
Strontium	10	100	78	154	127
Molybdenum	5	50	11	63	39
Aluminum	5	50	7	36	22
Nickel	4	40	8	32	17
Chromium	3	30	10	15	12

This station is located on the west bank of the Mississippi River immediately upstream from the mouth of the Yazoo River, approximately 290 miles below West Memphis. Samples are collected at the Corps of Engineers pier at the Delta Casting Yard about two miles north of the U. S. Highway 80 bridge.

There are no significant upstream pollution sources in the area. The city of Vicksburg, on the east bank, utilizes the Mississippi River as a source of drinking water.

In addition to elements listed above, single observations of silver (9.0 µg/l), cobalt (36 µg/l) and lead (45 µg/l) were reported at the Delta station.

MISSISSIPPI RIVER AT VICKSBURG, MISSISSIPPI

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	55.6	9	40	28
Boron	9	100	32	130	66
Iron	8	88.9	7	138	46
Manganese	5	55.6	1.1	4.0	2.4
Copper	7	77.8	5	9	7
Barium	9	100	14	94	50
Strontium	9	100	87	213	122
Aluminum	3	33.3	25	26	26
Molybdenum	3	33.3	9	47	34

This sampling point is at the raw water intake of the city of Vicksburg, Mississippi. It is immediately below the mouth of the Yazoo River which drains northwestern Mississippi. During high spring flows, most of the water is from the Yazoo River, while during low flows, most of the water is from the Mississippi River.

There are no known significant industrial or municipal sources of pollution immediately above the station. The city of Vicksburg obtains its water supply from the river. Most of the industries use city water and are located downstream from the station.

In addition to those elements tabulated, single occurrences of arsenic, nickel and vanadium at 56, 9 and 42 µg/l were recorded. Two occurrences each of lead (19 and 52 µg/l) and chromium (23 and 11 µg/l) were also observed. Cadmium, beryllium, silver and cobalt were never detected.

MISSISSIPPI RIVER NEAR NEW ROADS, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	100	7	46	22
Boron	7	100	44	200	87
Iron	4	57.1	15	70	50
Manganese	3	42.9	3.0	12	6.3
Copper	7	100	5	36	12
Barium	7	100	28	76	54
Strontium	6	85.7	98	158	133
Molybdenum	4	57.1	16	90	55
Chromium	3	42.9	9	11	9

The next to the last downstream station on the Mississippi River is located near New Roads, Louisiana approximately 163 miles above New Orleans. As the activation date for this station was May 1964, only seven samples have been included in the period reported.

In addition to the nine elements listed above, single occurrences of aluminum (26 µg/l), lead (45 µg/l) and vanadium (4 µg/l) were observed here. Cadmium, [illegible], beryllium, silver, nickel and cobalt were never detected.

MISSISSIPPI RIVER AT NEW ORLEANS, LOUISIANA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	12	66.7	5	59	23
Boron	18	100	22	463	77
Iron	13	72.2	8	59	22
Manganese	7	38.9	0.6	10.4	3.6
Copper	14	77.8	2	19	9
Barium	18	100	23	77	53
Strontium	18	100	92	216	133
Molybdenum	7	38.9	16	84	36
Aluminum	3	16.7	13	60	29
Lead	4	22.2	28	75	54
Chromium	4	22.2	5	10	8

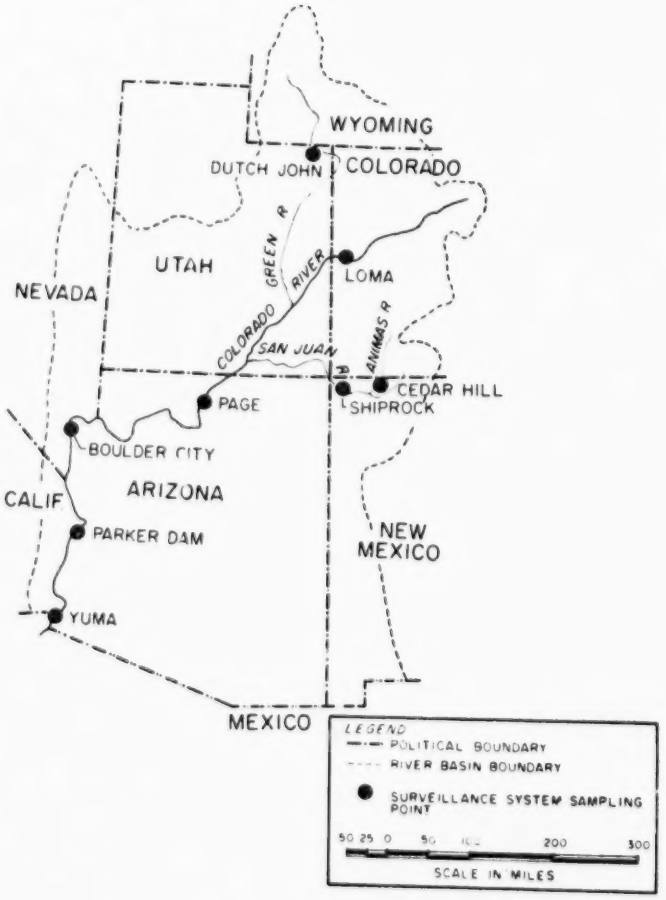
This station is the farthest downstream sampling point on the Mississippi River and is located 105 miles above the mouth. Samples are taken at the New Orleans municipal water treatment plant intake. Twenty miles upstream, primary sewage treatment plant effluent and wastes from petrochemical industries at Baton Rouge are discharged to the river. Ocean-going vessels navigate the river as far upstream as Baton Rouge.

Municipal water supplies taken from the Mississippi in the area of the station include those of New Orleans, Westwego, Gretna and Algiers, Louisiana, and Jefferson Parish.

In addition to the elements tabulated arsenic, nickel and vanadium were detected on single occasions at 126, 15 and 10 µg/l, respectively. Cadmium, beryllium, silver and cobalt were never observed.

BASIN 11

COLORADO RIVER



APPENDIX K

BASIN 11 – COLORADO RIVER

The Colorado River heads on the west slope of the Rocky Mountains in northern Colorado. This river flows nearly 1,400 miles in a generally southwesterly direction to the Gulf of California. Seven States drain wholly or in part to the Colorado from its 244,000 square mile U. S. watershed. The stream forms the boundary separating Arizona from California and a part of Nevada. For its last 80 miles, the river flows through Mexico, draining an additional 2,000 square miles south of the U. S. border.

Eight surveillance stations are located within this basin on four river systems. Five stations are on the Colorado mainstem and one each are located on the Green, Animas and San Juan Rivers. One hundred samples were analyzed from these four rivers during the time period here involved.

All elements included in the spectrographic program were observed at least once, except beryllium. Cadmium, arsenic, and cobalt were observed in 2% or less of the samples. Aluminum, lead, chromium and silver were observed 14 to 18% of the time; nickel and vanadium 8 and 9% of the time, respectively. Boron, barium and strontium were detected in over 98% of all samples, iron in 59%, and copper, molybdenum, manganese and zinc in 33 to 45%.

SUMMARY OF TRACE ELEMENTS

BASIN 11 – COLORADO RIVER

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	45	45	3	312	51
Cadmium	1	1	2	2	2
Arsenic	2	2	26	80	53
Boron	98	98	11	1800	179
Phosphorus	22	22	10	580	121
Iron	59	59	2	251	40
Molybdenum	37	37	10	444	130
Manganese	39	39	1.3	49	12
Aluminum	14	14	7	200	50
Beryllium	0	0	---	----	---
Copper	33	33	1	35	10
Silver	18	18	0.4	38	5.8
Nickel	8	8	3	26	12
Cobalt	2	2	10	11	11
Lead	15	15	14	64	32
Chromium	17	17	3	63	16
Vanadium	9	9	7	300	105
Barium	100	100	3	232	60
Strontium	100	100	115	3500	697

SAN JUAN – ANIMAS RIVERS

The Animas River is tributary to the San Juan; the San Juan River is tributary to the Colorado River. The two rivers begin at altitudes above 10,000 feet and flow over very steep courses in their upper reaches. Most of the flow in these river systems originates in Colorado. Flows through numerous dry washes or arroyos from occasional desert rains carry large sediment load to the San Juan. Below the Animas confluence with the San Juan at Farmington, New Mexico, a broad stream bed is cut into soft sandstones and marls, within which the dry-weather flow channel meanders.

While a wide variety of trace elements were observed in the Animas River at Cedar Hill, New Mexico, many go undetected in the San Juan River. The boron mean concentration in the San Juan was twice that observed in the Animas. The iron concentration also was higher in the San Juan, as was strontium. Aluminum was observed less frequently but in increased mean concentration in the San Juan.

ANIMAS RIVER AT CEDAR HILL, NEW MEXICO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	13	65	7	76	24
Boron	19	95	11	176	53
Iron	17	85	2	29	12
Manganese	7	35	1.3	10.5	3.6
Copper	10	50	2	10	5
Barium	20	100	13	113	43
Strontium	20	100	126	1200	368
Molybdenum	4	20	10	88	46
Aluminum	8	40	7	95	31
Silver	9	45	0.4	7.0	2.9
Nickel	4	20	3	16	7
Lead	11	55	14	52	30
Chromium	6	30	3	13	6
Vanadium	3	15	7	48	29

The Water Quality Surveillance System sampling station on the Animas River is located near the Colorado-New Mexico State line. Samples are collected from the bank at the gas pipeline crossing on the Heizer ranch. Two communities in Colorado – Silverton and Durango – discharge municipal wastes into the Animas. Aztec, New Mexico, 15 miles below the surveillance station, and Farmington, New Mexico, 14 miles below Aztec, use the river for municipal supply and waste disposal.

Water quality in the Animas is affected by uranium mine tailings and drainage near Silverton, Colorado. Extensive use is made of the stream for irrigation and there are oil and gas developments below this station.

Of the 19 elements included in the spectrographic program, only beryllium was undetected. Cadmium, arsenic and cobalt were each observed on one occasion at 2, 80 and 10 µg/l, respectively.

SAN JUAN RIVER AT SHIPROCK, NEW MEXICO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	63.6	16	74	35
Boron	11	100	25	295	123
Iron	10	90.9	14	245	56
Manganese	5	45.5	3.6	12	6.9
Copper	4	36.4	5	18	10
Barium	11	100	15	108	57
Strontium	11	100	147	1270	615
Aluminum	3	27.3	21	200	85

The surveillance system station at Shiprock is about 22 miles upstream from the point where the San Juan River enters Utah after flowing through Colorado for about three miles near the Four Corners Area. Samples are collected just upstream from the water intake for the U. S. Bureau of Mines helium plant. Several small communities are located above the surveillance station. Farmington, New Mexico with a population of about 25,000 is 59 miles upstream. Extensive irrigation near Farmington can be expected to increase when waters impound behind Navajo Dam and when the irrigation works are completed. Natural gas deposits are found along the river above Farmington and a uranium mill is located a short distance above the surveillance station.

In addition to those tabulated above, the following elements and concentrations were detected: molybdenum (15 and 69 µg/l), silver (1.4 and 3.6 µg/l), lead (14 µg/l) and vanadium (217 µg/l). Cadmium, arsenic, beryllium, nickel, cobalt and chromium were all either absent or below the detection limit.

GREEN RIVER AT DUTCH JOHN, UTAH

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	44.4	5	36	19
Boron	9	100	60	215	135
Iron	6	66.7	6	109	41
Manganese	4	44.4	3.3	15	9.0
Copper	5	55.6	1	16	9
Barium	9	100	11	196	64
Strontium	9	100	318	437	375

The Green River is tributary to the Colorado in southeastern Utah. This stream flows from southwestern Wyoming to Utah, joining the Colorado below Moab, Utah. The Water Quality Surveillance System station at Dutch John, Utah, is about 30 miles downstream from the Wyoming-Utah State line. Samples are collected at Flaming Gorge Dam powerhouse. Downstream, the Green River enters and flows through Colorado for a short distance before reentering Utah and proceeding to its confluence with the Colorado in southeast Utah.

The nearest municipal discharge to the Dutch John station is about 90 miles upstream at Green River, Wyoming. Grazing of sheep and cattle is a major land use, as is irrigation. A large portion of the irrigated cropland is in Wyoming. Principal crops are alfalfa, natural hay, oats and clover.

Molybdenum (95 and 142 µg/l), aluminum (43 µg/l), silver (2.2 and 4.5 µg/l), nickel (7 µg/l) and cobalt (11 µg/l) were observed at the respective levels indicated. Cadmium, arsenic, beryllium, lead, chromium and vanadium were never detected.

THE COLORADO RIVER

Most of the Colorado River's drainage area is arid land. Precipitation in the basin varies from 2½ inches per year along the Mexican Border to 30 inches per year in the higher elevations along the Continental Divide. Annual evaporation varies from about 32 inches in the upper basin to almost 86 inches in the California-Arizona desert area. Streamflow in the lower Colorado is presently regulated. Further dam construction underway and planned will bring the entire river under regulation.

There are extensive irrigation and water power projects throughout the river basin. In addition, a portion of the Colorado flow is diverted and exported to southern California for municipal and industrial uses. The principal industrial activities in the basin are mining and ore processing. The extent of these activities varies as to location and time. Past mining activities have left their scars on the land, and mine drainage and tailings piles still exert an adverse influence on the quality of the water draining some areas.

The Colorado plateau extends over portions of Utah, Colorado, Arizona and New Mexico. The lower portion of the plateau is largely composed of flat-lying sandstones, shales, and limestones which have been deeply incised by the river system, most notably in the Grand Canyon. Because of the land erosion, the Colorado River carries a heavy silt load.

Five water quality sampling stations are located on the Colorado River at Loma, Colorado; Page, Arizona; Boulder City, Nevada; Parker Dam, California and Yuma, Arizona. Sixty samples from the Colorado were analyzed within the time period. The zinc mean value increased both in frequency and concentration between Loma and Parker Dam, probably due to the Green and San Juan Rivers. A decrease was then noted. Iron, which remained about the same in frequency, showed this same increase in concentration, varying from 35-84 μg/l.

Between Loma, Colorado and Yuma, Arizona, a distance of over 1,000 river miles, the boron mean level increased from 109 to 656 μg/l. Strontium averaged about 650 μg/l between Loma and Boulder City and then tripled to over 1800 μg/l at Yuma, Arizona. Molybdenum, although not too regular in appearance, decreased over the same distance.

Cadmium, beryllium and cobalt were never observed at measurable levels. Arsenic, aluminum, nickel and lead were found in less than 5% of the samples. Silver and vanadium were found in 8%, while chromium was detected in about 18% of the samples.

COLORADO RIVER AT LOMA, COLORADO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Boron	22	100	18	232	109
Iron	11	50.0	15	62	35
Manganese	11	50.0	3.4	49	18
Copper	7	31.8	4	35	20
Barium	22	100	3	82	40
Strontium	22	100	203	1800	667
Molybdenum	18	81.8	20	444	194
Silver	3	13.6	3.0	38	16.8
Chromium	5	22.7	4	19	10
Vanadium	5	22.7	29	300	129

This is the farthest upstream surveillance station on the Colorado River and is located approximately 15 river miles above the Colorado-Utah State line. Samples are collected from the north bank of the river, two miles south of Loma. The Colorado heads roughly 250 miles upstream from this point.

Irrigated agriculture above the Loma station produces fruit, forage, grains and truck farm products. Upstream industries include uranium plants at Rifle, Grand Junction and Gunnison, and an oil shale extraction plant at Rifle. Municipal waste is discharged by three upstream communities within 21 miles of this station. There is a gasoline and coke refinery one mile upstream.

This station showed more positive occurrences of vanadium than any other in the entire surveillance system. In addition to those elements listed above, single occurrences of zinc at 13 µg/l and aluminum at 29 µg/l were recorded. Cadmium, arsenic, beryllium, nickel, cobalt and lead were never detected.

COLORADO RIVER AT PAGE, ARIZONA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	4	44.4	3	77	29
Boron	9	100	86	228	142
Iron	4	44.4	29	127	75
Manganese	3	33.3	5.3	9.0	7.1
Barium	9	100	30	91	59
Strontium	9	100	288	1250	645

The Page, Arizona station is approximately five miles below the Arizona-Utah State line, and 375 miles below the Loma, Colorado station. Samples are taken from the Page municipal water treatment plant. Moab, Utah, about 150 miles upstream, is the nearest community. The Green and San Juan Rivers are confluent to the Colorado River above Page and below Loma, Colorado; both tributaries have surveillance system stations.

Molybdenum at 48 and 100 µg/l, arsenic at 26 µg/l, copper at 3 and 10 µg/l, silver at 3.5 µg/l and chromium at 11 µg/l were detected in certain samples. Cadmium, aluminum, beryllium, nickel, cobalt, lead and vanadium were not detected.

COLORADO RIVER NEAR BOULDER CITY, NEVADA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	50	10	259	96
Boron	10	100	90	620	197
Iron	4	40	17	137	51
Manganese	4	40	3.3	26	15
Barium	10	100	50	232	90
Strontium	10	100	115	1220	658
Molybdenum	3	30	33	165	98

Boulder City, Nevada lies 360 miles below Page, Arizona and 415 miles above the mouth of the Colorado River. Water samples are taken from the booster pump station of the Boulder City intake which taps Hoover Dam penstocks. The intake elevation is variable.

Hoover Dam created Lake Mead which has a detention time of about two years for the average Colorado River flow. The evaporation rate is about seven feet per year. Lake Mead is a recreational water and receives some pollution from this source. Above Lake Mead, the river flows through the Grand Canyon of the Colorado.

Two occurrences each of lead (36 and 64 µg/l) and chromium (19 and 22 µg/l) and single occurrences of copper (23 µg/l) and silver (13 µg/l) were recorded. Cadmium, arsenic, aluminum, beryllium, nickel, cobalt and vanadium were never detected.

COLORADO RIVER ABOVE PARKER DAM, ARIZONA-CALIFORNIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	100	12	312	104
Boron	9	100	95	1036	271
Iron	4	44.4	2	251	84
Manganese	3	33.3	4.0	20	12.5
Copper	3	33.3	4	20	10
Barium	9	100	27	156	94
Strontium	9	100	438	1221	737
Molybdenum	4	44.4	33	74	52

Parker Dam lies 157 river miles below Boulder City, Nevada, 167 miles above Yuma, Arizona, and approximately 258 miles above the mouth of the Colorado River. This water quality surveillance station is located in the Whitset pumping plant which diverts Colorado River water from Lake Havasu to the Metropolitan Water District of Southern California. The Los Angeles and San Diego metropolitan areas use this water as a major portion of their municipal supplies. A portion of this diverted water is used also for industrial purposes and to recharge ground water aquifers.

No other municipal, industrial or agricultural uses are made of Colorado River water in the Parker Dam-Boulder City reach. Needles, California, about 70 miles upstream, draws it water supply from wells and discharges its wastes through lagoons to the main stem of the Colorado.

Total dissolved salt concentration, approximately one-third that found at Yuma, permits somewhat better limits of detection at this station. In addition to those elements tabulated, nickel at 7 and 26 µg/l, lead at 38 µg/l and chromium at 36 µg/l were detected. Cadmium, arsenic, aluminum, beryllium, silver, cobalt and vanadium were never detected.

COLORADO RIVER AT YUMA, ARIZONA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	2	20	13	80	46
Boron	9	90	313	1800	656
Iron	3	30	34	72	56
Manganese	2	20	12	28	20
Barium	10	100	38	121	74
Strontium	10	100	836	3500	1852

The Yuma, Arizona station provides surveillance on the Colorado before the river enters Mexico. Samples are collected from the former intake of the Arizona Water Company. The Colorado River is a source of irrigation water for the extensive developments above Yuma and receives the irrigation return drainage.

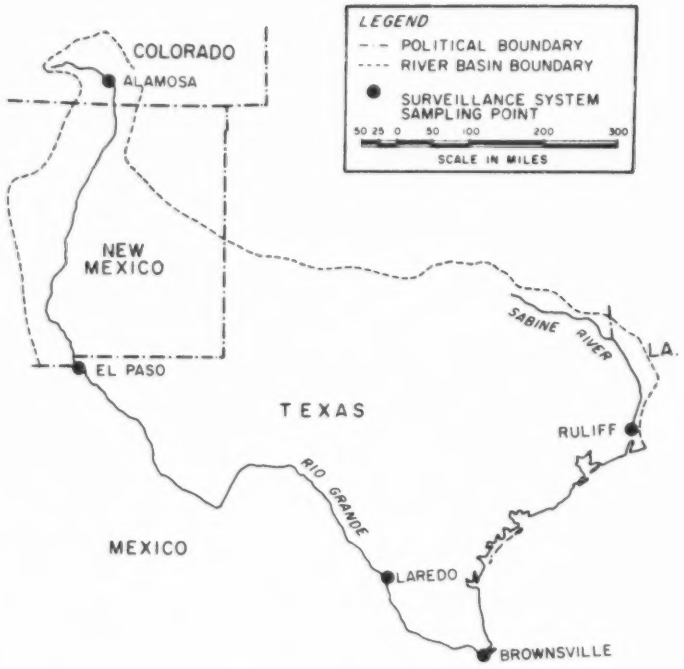
The Yuma station is directly influenced by the Wellton-Mohawk irrigation district drainage and the Gila River which enters the Colorado River immediately upstream. This station is 10 miles above the Mexican border approximately 90 miles above the mouth of the river. Yuma discharges its municipal waste into the Colorado River below this station.

As shown in the table, strontium and boron concentrations were extremely high, ranging from 835 to 3500 µg/l and 313 to 1800 µg/l, respectively. Except for barium, very few trace elements other than those shown above were detected in measurable quantities because the high dissolved salt content of the samples permits only slight concentration of the elements involved.

Single occurrences of aluminum at 125 µg/l, copper at 7 µg/l and nickel at 25 µg/l, plus two occurrences of chromium at 34 and 63 µg/l were recorded. Cadmium, arsenic, beryllium, silver, cobalt, lead and vanadium were never detected.

BASIN 12

WESTERN GULF



APPENDIX L

BASIN 12 – WESTERN GULF

The Western Gulf Drainage Basin includes most of Texas and New Mexico plus small portions of Colorado and Louisiana. Topography varies from the sea level coastal plain to the 14,000 foot peaks of southern Colorado.

Two river systems within the Western Gulf Basin, the Sabine on the east and the Rio Grande on the west, are included within the Water Quality Surveillance System. Five sampling stations are located in the basin, four on the Rio Grande and one on the Sabine River.

Forty-seven samples from this basin were analyzed within the time period involved. All contained barium and strontium; boron was found in 98% of the samples. Iron occurred with a frequency of 70%; manganese, copper and zinc were found only 38-49% of the time. Cadmium, arsenic, nickel, lead, chromium and vanadium were found in 6% or less of the samples. Beryllium and cobalt were never observed at measurable levels in any sample.

SUMMARY OF TRACE ELEMENTS

BASIN 12 – WESTERN GULF

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	23	48.9	6	405	92
Cadmium	1	2.1	10	10	10
Arsenic	2	4.3	20	24	22
Boron	46	97.9	34	1726	289
Phosphorus	11	23.4	18	570	173
Iron	33	70.2	3	952	173
Molybdenum	5	10.6	4	59	24
Manganese	18	38.3	0.6	42	10
Aluminum	10	21.3	5	924	333
Beryllium	0	0	--	----	---
Copper	19	40.4	2	38	11
Silver	2	4.3	0.4	6.6	3.5
Nickel	1	2.1	3	3	3
Cobalt	0	0	--	----	---
Lead	1	2.1	4	4	4
Chromium	3	6.4	5	56	25
Vanadium	1	2.1	9	9	9
Barium	47	100	10	174	67
Strontium	47	100	21	2720	652

SABINE RIVER NEAR RULIFF, TEXAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	100	25	405	162
Boron	8	80	46	331	103
Iron	10	100	28	952	373
Manganese	8	80	0.6	28	7.8
Copper	10	100	4	34	14
Barium	10	100	18	70	50
Strontium	10	100	21	203	112
Aluminum	8	80	9	924	400

The Sabine River begins at an elevation of 500 feet in east Texas, flows 200 miles to the southeast, and then bends to the south to form the Texas-Louisiana border for 180 miles. The river discharges into Sabine Lake near Port Arthur and thence into the Gulf of Mexico. The total drainage area is about 9,700 square miles.

The sampling station is located on the Sabine River Authority Canal which supplies industrial and agricultural water to the Orange-Beaumont area. Samples are collected at the Sabine River Authority pumping plant. The 1962 Inventory of Municipal Waste Facilities showed 34 communities in the Texas and Louisiana area discharging both treated and untreated municipal wastes to the Sabine River mainstem or its tributaries. There are, however, no significant discharges within 100 miles of the Ruliff station. Oil fields have been developed in the upstream drainage basin. Some diversion is made for rice irrigation.

The highest concentrations of zinc, iron and aluminum within this basin were observed in the Sabine River in 80% or more of the samples. Single occurrences of molybdenum, silver, nickel and lead at 34, 0.4, 3 and 5 µg/l, respectively, were also recorded.

THE RIO GRANDE

The Rio Grande drains an area of 182,200 square miles, about one-half of which are in Mexico. The river heads on the eastern flank of the San Juan Mountains in south-central Colorado. It flows southward through New Mexico and thence southeasterly to form the international boundary between the United States and Mexico.

The San Luis Valley of Colorado, a part of the Rio Grande watershed, is an area of extensive agricultural development. The river flow is affected by irrigation withdrawals and returns and by the operation of storage reservoirs. Upon entering New Mexico, the Rio Grande traverses an arid area. Two large mainstem impoundments, above El Paso -- Elephant Butte and Cabello Reservoirs -- store most of the river flow from September to March for release during the growing season. Below El Paso, the Mexico drainage contributes little surface runoff. In the vicinity of Brownsville, Texas the stream supports an extensively irrigated agriculture.

There are four water quality sampling stations on the Rio Grande. The uppermost is at Alamosa, Colorado at river mile 1755. Approximately 500 miles down river is the El Paso station. The third station at Laredo, Texas is at river mile 356 and the Brownsville station is farthest downstream just 52 miles above the mouth of the Rio Grande.

The trace element mean levels at Alamosa were the lowest observed anywhere in the Rio Grande Basin. Zinc, manganese and copper were infrequently found. Only boron, barium and strontium occurred regularly. The strontium levels in the Rio Grande are some of the highest observed in any river within the national system.

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RIO GRANDE BELOW ALAMOSA, COLORADO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Boron	10	100	34	245	106
Iron	7	70	6	67	27
Copper	3	30	4	6	5
Barium	10	100	10	50	33
Strontium	10	100	86	308	207

Samples are collected from the Colorado State Highway 142 bridge. This is the uppermost surveillance station on the Rio Grande River and is located approximately 10 miles above the Colorado-New Mexico State line in the San Luis Valley. This valley supports extensive agriculture, potatoes being the principal crop. In parts of the valley, water tables are quite high and the fields must be extensively drained to prevent mineral buildup in the root zone.

The nearest upstream municipal waste discharges include those of Alamosa, Del Norte, and Monte Vista, Colorado. An oil refinery and a dairy also discharge wastes to the Rio Grande about three miles above the Alamosa station.

Boron, barium, and strontium levels are lower at this station than at others in this basin. Zinc was observed on two occasions at 10 µg/l. Manganese at 1.2 and 2.0 µg/l was also observed, as were single occurrences of molybdenum (59 µg/l), aluminum (5 µg/l), chromium (15 µg/l) and vanadium (9 µg/l). Cadmium, arsenic, beryllium, silver, nickel, cobalt and lead were never detected.

RIO GRANDE AT EL PASO, TEXAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	5	55.6	6	126	51
Boron	9	100	155	1726	542
Iron	4	44.4	3	119	56
Barium	9	100	35	120	63
Strontium	9	100	480	2720	1290

The El Paso surveillance system station is located near the point where the river becomes the international boundary between the United States and Mexico. For approximately 20 miles above this point the river is the interstate boundary between New Mexico and Texas. Samples are collected from the El Paso municipal water plant intake.

The Rio Grande at this point is regulated by Elephant Butte and Cabello Reservoirs upstream in New Mexico. From about mid-September to early March the flow at El Paso is in the range of one to several cubic feet per second. La Cruces, New Mexico and Anthony, Texas, 45 and 19 miles upstream, respectively, discharge secondary treatment sewage effluents to the stream. El Paso, Texas, and Juarez, Mexico obtain half of their minicipal water supplies from the Rio Grande.

Manganese at 20 and 42 μg/l, copper at 3 and 38 μg/l and arsenic at 24 μg/l were recorded in addition to the five elements tabulated above. Cadmium, molybdenum, aluminum, beryllium, silver, nickel, cobalt, lead, chromium and vanadium were never detected.

RIO GRANDE AT LAREDO, TEXAS

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	3	30	22	78	52
Boron	10	100	113	880	269
Iron	6	60	13	238	79
Manganese	2	20	3.0	3.7	3.3
Copper	2	20	4	15	10
Barium	10	100	23	174	89
Strontium	10	100	448	1815	822

The Laredo station is 892 river miles below the El Paso surveillance system station. Some distance upstream the Pecos River, which drains some 35,000 square miles, has joined the Rio Grande. Samples are collected from the intake of the Laredo municipal water plant. The Rio Grande flows through sparsely populated areas from El Paso to Laredo, and only limited use is made of this reach of the river.

The same general conditions were observed at the Laredo station as at Brownsville. Barium, boron, and strontium were observed in all samples. Iron occurred frequently and zinc, manganese and copper were observed occasionally. In addition, single occurrences of cadmium (10 µg/l), molybdenum (11 µg/l), aluminum (135 µg/l), silver (6.6 µg/l) and chromium (56 µg/l) were recorded. Arsenic, beryllium, nickel, cobalt, lead and vanadium were never detected.

RIO GRANDE AT BROWNSVILLE, TEXAS

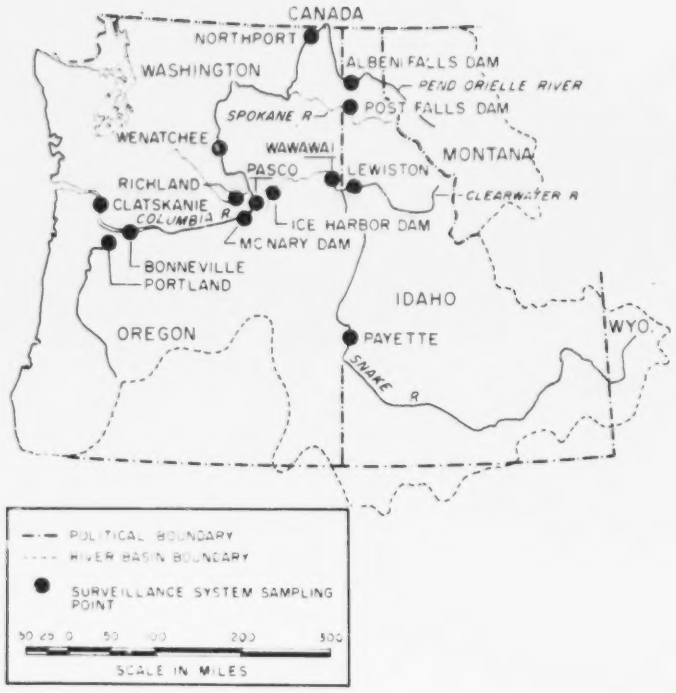
ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	3	33.3	6	38	18
Boron	9	100	246	820	423
Iron	6	66.7	3	823	183
Manganese	4	44.4	4.8	29	12
Barium	8	88.9	84	130	108
Strontium	8	88.9	585	1400	952

The Brownsville station is the terminal station on the Rio Grande. Samples are collected at the intake of Brownsville No. 1 Water Plant. Falcon Reservoir, on the mainstem between Brownsville and Laredo, provides irrigation and municipal water supplies for communities of the "Magic Valley" at the southern tip of Texas. This agricultural district supports a diversified production of cotton, vegetables, corn, grains and citrus fruit. Most of the industrial wastes result from canning and packing operations. Municipal and industrial wastes in this valley, for the most part, are diverted into the Gulf of Mexico via arroyos and floodways. Brownsville is an exception; this city discharges municipal wastes into the Rio Grande from its treatment plant. There are no communities downstream.

Two occurrences each of molybdenum (4 and 11 µg/l) and copper (2 and 4 µg/l) plus single occurrences of arsenic (20 µg/l) and lead (4 µg/l) were recorded. Cadmium, aluminum, silver, nickel, cobalt, chromium and vanadium were never detected.

BASIN 13

PACIFIC NORTHWEST



APPENDIX M

BASIN 13 – PACIFIC NORTHWEST

The Pacific Northwest Basin includes the Columbia River system and the small Pacific Coast drainage basins along the western flanks of the Cascade and Coast Ranges in Oregon and Washington. At present, only the Columbia Basin is included in the Water Quality Surveillance System.

The Pacific Northwest drainage basin totals about 259,000 square miles, of which 220,000 lie in the United States. The Basin embraces Washington and Oregon, nearly all of Idaho, western Montana and small portions of Wyoming, Utah and Nevada. In general, runoff is high in this basin and mineral concentrations are fairly low except where the water has been used for irrigation.

Fourteen surveillance stations are located in this basin: six on the Columbia, three on the Snake and one each on the Clearwater, the Willamette, and Pend Oreille, the Yakima and the Spokane Rivers. Samples analyzed from these stations during the time period involved totaled 162.

Of the 19 elements routinely monitored, only barium was found in all samples. All of the elements occurred at least once. Cadmium, beryllium, cobalt and vanadium were found in less than 6% of the samples; arsenic and nickel occurred 8.5 and 10.5% of the time. Lead, chromium, aluminum and molybdenum occurred in 23 to 39% of the samples; manganese in 51%. Iron, copper and zinc were found in 80 to 90%. Boron occurred with a frequency of over 93% and strontium over 99%. The mean concentrations of these elements were all below the national averages.

SUMMARY OF TRACE ELEMENTS

BASIN 13 – PACIFIC NORTHWEST

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	146	90.1	2	330	40
Cadmium	4	2.5	1	13	5
Arsenic	14	8.6	16	300	68
Boron	152	93.8	4	148	30
Phosphorus	85	52.5	2	183	47
Iron	130	80.2	2	256	32
Molybdenum	63	38.9	2	128	30
Manganese	83	51.2	0.4	28	2.8
Aluminum	49	30.2	3	179	30
Beryllium	1	0.6	0.02	0.02	0.02
Copper	141	87.0	1	37	9
Silver	14	8.6	0.1	3.7	0.9
Nickel	17	10.5	1	50	10
Cobalt	6	3.7	1	17	8
Lead	37	22.8	4	79	15
Chromium	53	32.7	1	36	6
Vanadium	10	6.2	3	20	13
Barium	162	100	2	100	27
Strontium	161	99.4	3	334	68

WILLAMETTE RIVER AT PORTLAND, OREGON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	90.9	12	70	28
Boron	11	100	6	74	22
Iron	11	100	15	138	59
Manganese	9	81.8	0.4	3.2	1.4
Copper	10	90.9	4	17	7
Barium	11	100	4	25	10
Strontium	11	100	16	32	24
Molybdenum	4	36.4	3	28	15
Aluminum	5	45.5	10	179	85

The Willamette river rises in southwest Oregon and flows northward 300 miles to its confluence with the Columbia River at Portland. It is navigable to Eugene, 178 miles upstream. The Willamette drains the most heavily populated part of Oregon. Agriculture, food processing, and lumbering operations are the principal economic activities.

The Portland sampling station is located at Swan Island, 8½ miles above the Willamette's confluence with the Columbia. Two pulp mills are located at Oregon City, approximately 18 miles above the station. The largest municipality contributing waste upstream from the station is Salem, Oregon.

In addition to those elements shown above, single occurrences of nickel and chromium at 1 µg/l and vanadium at 3 µg/l were recorded. Cadmium, arsenic, beryllium, silver, cobalt and lead, however, were never recorded.

PEND OREILLE RIVER AT ALBENI FALLS DAM, IDAHO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	90.9	3	39	15
Boron	11	100	4	27	13
Iron	10	90.9	2	74	18
Manganese	7	63.6	0.4	7.0	2.4
Copper	10	90.9	3	11	5
Barium	11	100	2	100	39
Strontium	11	100	15	69	33
Molybdenum	7	63.6	13	55	24
Aluminum	3	27.3	3	15	7
Lead	4	36.4	10	20	14
Chromium	3	27.3	2	13	6

The Pend Oreille River begins as an outflow from Pend Oreille Lake in Northern Idaho and receives drainage from Washington, Idaho, western Montana, and Canada. It flows 119 miles west-northwest to the Columbia River in Canada. Most of the drainage basin is covered by natural forests.

This water quality station is located in the Albeni Falls Dam powerhouse. This dam near the Washington-Idaho border creates an impoundment which extends upstream to Pend Oreille Lake, a large natural lake. The principal stream feeding Lake Pend Oreille is the Clark Fork River which drains a large portion of western Montana.

The principal community on Pend Oreille Lake is Sandpoint, Idaho, which discharges treated wastes into the lake near its outlet to the Pend Oreille River. Priest River, Idaho discharges treated municipal waste to Pend Oreille River above the surveillance system station. No major municipal waste loads are discharged to the Pend Oreille River below the station.

Two occurrences each of nickel (2 and 13 µg/l) and cobalt (1 and 14 µg/l), plus single silver (0.2 µg/l), vanadium (17 µg/l) and cadmium (2 µg/l) values were observed. Only arsenic and beryllium, of the 19 programmed elements, were never detected.

YAKIMA RIVER AT RICHLAND, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	10	58.8	2	31	11
Boron	16	94.1	17	42	24
Iron	12	70.6	3	92	19
Manganese	7	41.2	1.3	9.6	4.5
Copper	13	76.5	3	8	5
Barium	17	100	12	37	21
Strontium	17	100	42	129	74
Molybdenum	9	52.9	4	77	39
Lead	4	23.5	5	22	13

The Yakima River rises on the east slope of the Cascade Range and flows 203 miles to the Columbia. This stream is used extensively for irrigation and hydroelectric power.

The Richland, Washington sampling station is located at the city pumping station near the terminus of the Yakima River basin. Extensive irrigation in the basin supports an agricultural economy which produces such diversified crops as fruits, including apples, cherries, and pears; hay and grain crops; vegetables; and such other crops as sugar beets, potatoes and hops. Over one-quarter million acres are irrigated in the Yakima basin. Yakima, Washington, the principal upstream community lies some 90 miles above the surveillance station and discharges treated wastes to the Yakima River. Food processing plants, lumber yards, and some manufacturing plants are located in and near the city. Food processing plants which operate seasonally generate large quantities of industrial wastes. These wastes are extensively treated by lagooning and applied by sprinkler to land areas. During the irrigation season, a high percentage of the river flow at the surveillance station is irrigation return drainage.

Two occurrences each of aluminum at 5 and 10 µg/l and vanadium at 18 and 20 µg/l, plus one of chromium at 4 µg/l were reported. Cadmium, arsenic, beryllium, silver, nickel and cobalt were never detected.

SPOKANE RIVER AT POST FALLS DAM, IDAHO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	9	100	72	330	203
Boron	8	88.9	6	17	10
Iron	9	100	2	132	21
Manganese	6	66.7	0.4	2.0	1.1
Copper	9	100	4	17	9
Barium	9	100	9	29	17
Strontium	9	100	3	14	10

The Spokane River originates below Coeur d'Alene Lake in western Idaho. The lake receives drainage from Idaho and western Montana. The river flows in a westward course to join the Columbia River. The principal economic activities in this area are lumbering, wheat, fruit, livestock and mining and associated processing.

This station is located in the Post Falls Dam powerhouse two miles upstream from the Washington-Idaho State line and seven miles downstream from Coeur d'Alene, Idaho. This city draws its municipal water supply from Coeur d'Alene Lake and discharges its treated sewage to the river above the sampling station. Lumbering is the principal industry in this area. The lower reach of the Spokane River is in pool above Grand Coulee Dam after flowing through Spokane, Washington.

In addition to those elements listed above, cadmium at 1 and 4 µg/l, nickel at 1 and 3 µg/l, lead at 4 and 8 µg/l and chromium at 3 and 2 µg/l as well as molybdenum at 10 µg/l, aluminum at 20 µg/l and vanadium at 6 µg/l were observed.

CLEARWATER RIVER AT LEWISTON, IDAHO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	9	100	13	99	43
Boron	8	88.9	4	23	12
Iron	9	100	10	95	39
Manganese	6	66.7	0.4	1.1	0.7
Copper	9	100	5	37	22
Barium	9	100	8	36	15
Strontium	9	100	15	59	30
Aluminum	6	66.7	6	135	41

The Clearwater River is tributary to the Snake River and drains north-central Idaho and a small portion of western Washington. Much of the headwater area is in natural forests; lumbering and lumber mills are the principal economic activity. Some farming is also carried on.

The Clearwater is monitored by the Water Quality Surveillance System at the municipal water plant intake, approximately two miles above its confluence with the Snake River. There are minor municipal discharges located some 40 miles upstream from the station. The nearby area is rather hilly and stock raising is the principal agricultural activity. A kraft pulp mill is located above the station and utiiizes 30 to 40 million gallons per day of the river water. Wastes from this plant are discharged to the confluence of the Snake and Clearwater Rivers below the surveillance station. There is a log pond associated with this plant.

In addition to two nickel values of 2 and 41 μg/l, single observations of arsenic at 16 μg/l, molybdenum at 15 μg/l, beryllium at 0.02 μg/l, silver at 0.1 μg/l, lead at 5 μg/l, chromium at 12 μg/l, and vanadium at 8 μg/l were recorded. Cadmium and cobalt were never detected.

THE SNAKE RIVER

The Snake River is the major tributary of the Columbia. It rises in Yellowstone National Park and flows for about 1,000 miles to join the Columbia near Pasco, Washington. This stream has cut a canyon to a depth of 5,500 feet. Idaho's major population centers are located along the Snake River where both private and Federal irrigation projects are active.

Three Water Quality Surveillance Stations are located on the Snake River at Wawawai and Ice Harbor Dam, Washington and Payette, Idaho. The Ice Harbor Dam station lies farthest downstream, just 10 miles above the point where the Snake River discharges to the Columbia. The Wawawai station is located 100 miles upstream. Payette is the uppermost station, lying 255 miles above Wawawai and 635 miles below the headwaters of the Snake River.

Thirty-six samples from these three stations were analyzed within the time period here reported. The zinc mean level remained quite constant, varying only from 34 to 46 μg/l.

The iron and manganese mean concentrations showed slight decreases. The boron mean concentration of 86 μg/l at Payette was apparently diluted by the Clearwater River to 12 μg/l and was recorded at 54 μg/l over the remaining distance. Barium, strontium, and molybdenum concentrations also reflected the dilution effect of the Clearwater River.

SNAKE RIVER AT PAYETTE, IDAHO

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	15	93.8	4	103	34
Boron	15	93.8	30	125	86
Iron	9	56.3	2	155	41
Manganese	5	31.3	1.5	28	10
Copper	8	50.0	2	30	10
Barium	16	100	9	81	36
Strontium	15	93.8	30	334	177
Molybdenum	8	50.0	21	128	71

The Payette station is located at the highway bridge crossing the Snake River. It is the uppermost sampling point on the river, and is located in the reach of the river that forms the Oregon-Idaho border. Municipal wastes are discharged to the Snake River within four miles upstream from the station. Also, upstream, about 2.5 million acres are irrigated for growing sugar beets, potatoes, and grains, the principal crops. The associated food processing plants discharge their wastes to the Snake River and its tributaries above the Payette station.

Two occurrences of silver at 0.5 and 1.3 µg/l and single occurrences of cadmium, arsenic and chromium values of 13, 300 and 2 µg/l, respectively, were recorded. Aluminum, beryllium, nickel, cobalt, lead and vanadium were never detected.

SNAKE RIVER AT WAWAWAI, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	72.7	3	70	37
Boron	10	90.9	14	92	54
Iron	8	72.7	6	256	62
Copper	6	54.5	4	10	6
Barium	11	100	7	52	26
Strontium	11	100	25	150	88
Molybdenum	3	27.3	2	64	37
Chromium	3	27.3	4	36	.17

This sampling point in the surveillance system is located at the pumping station of the I. E. Wilson Farm about 25 miles below the point where the Snake River bends westward through Washington. Clarkston, Washington and Lewiston, Idaho 25 miles upstream are the two communities that may influence water quality at this station by discharging treated sewage. Pulp mill wastes are also discharged to the river in the Lewiston-Clarkston area. Irrigation water is diverted from the stream, principally in the southern Idaho portion of the drainage. The Clearwater River is a tributary to the Snake River at Lewiston, Idaho.

Two occurrences each of manganese (2.3 and 9.6 µg/l), aluminum (6 and 16 µg/l) and nickel (1 and 50 µg/l), plus single observations of silver (1.4 µg/l), lead (11 µg/l) and vanadium (9 µg/l) were recorded. Cadmium, arsenic, beryllium and cobalt were not detected.

SNAKE RIVER AT ICE HARBOR DAM, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	77.8	6	201	46
Boron	8	88.9	17	148	54
Iron	9	100	4	48	21
Manganese	4	44.4	1 5	5.9	3.0
Copper	9	100	10	19	14
Barium	9	100	14	33	24
Strontium	9	100	28	146	92
Molybdenum	3	33.3	8	60	32
Aluminum	3	33.3	8	49	27

This surveillance system station, located in the powerhouse at Ice Harbor Dam, Washington, monitors the discharge of the Snake River to the Columbia River. There are no municipal water users for 100 miles upstream from this station. The Snake River flow is regulated and provides for an extensive irrigated agriculture.

Single occurrences of nickel (2 µg/l), cobalt (3 µg/l), lead (16 µg/l), chromium (10 µg/l) and vanadium (19 µg/l) were reported. Cadmium, arsenic, beryllium and silver were never detected.

THE COLUMBIA RIVER

The Columbia River originates in Columbia Lake, in southeastern British Columbia, Canada. It flows 190 miles northwest, thence bends sharply to the south, flowing 270 miles to cross the international boundary and continues on across Washington for another 750 miles to the Pacific Ocean. The fall from source to tidewater is about 2,700 feet. Many of the Columbia's tributaries, however, have even greater drops between source and mouth, varying in some instances from 3,000 to 6,000 feet.

The principal tributary is the Snake River whose general drainage is the southeastern half of the United States portion of the basin. Other major tributaries to the Columbia are the Pend Oreille, Spokane, Yakima, and Willamette Rivers, plus numerous smaller streams along its entire length.

The Cascade Mountain Range lies a short distance inland from the Pacific Coast. Two hundred to 300 miles east of the Cascades is the main range of the northern Rocky Mountains. Ninety-one percent of the land area of the Columbia River Basin, accounting for 75 percent of the runoff, lies in between.

The intervening plateau includes several low mountain ranges and rolling hills, with precipitous canyons in many places. Much of this area is composed of enormous sheets of horizontal lava flows, covered with surface materials suitable for a variety of agricultural purposes. Nearly all of the interior lands suitable for cultivation are semiarid or near-deserts.

The lower, drier mountain slopes and the dry, interior plateaus are covered by sagebrush and other desert vegetation. The surrounding humid mountains are covered with forests of varying types and densities.

Six Water Quality Surveillance Stations are located on the Columbia River. The uppermost station is at Northport, Washington, approximately 14 miles downstream from the Canadian border. Some 275 miles farther downstream at Wenatchee, Washington is the next station. The Hanford Atomic Energy Plant and the outflow of the Yakima River are monitored by a third station at Pasco, Washington. Two other stations are located at McNary Dam and Bonneville Dam, respectively. The terminal station, approximately 54 miles above the point where the Columbia empties into the Pacific Ocean, is at Clatskanie, Oregon.

Sixty-nine samples were analyzed from these six Columbia River stations during the time period involved. All contained barium and strontium; cadmium and beryllium were never detected. Except for a single occurrence at 239 µg/l at Pasco, the zinc concentrations in the Columbia River never exceeded 50 µg/l, although this element was detected in over 98% of the samples.

The boron mean level, which ranged from 10 to 34 µg/l, increased slightly below Pasco, Washington and was observed with an overall frequency of over 94%. Copper occurred with a frequency of 97%, the mean ranging from 23-35 µg/l. Iron was observed at measurable levels in 77% of the samples with varying means of 22 to 33 µg/l. The frequency of manganese was even less at 53%, while the highest observed concentration was only 8.1 µg/l. The manganese mean concentration at the six stations varied from 1.5 to 3.6 µg/l.

Molybdenum and aluminum occurred with a frequency of 39%. Chromium increased in frequency from 25% at Northport to 67% at the lower four stations. Mean concentrations ranged from 3 to 8 μg/l, the minimum being 1 μg/l and the maximum 22 μg/l. Lead was observed in 35% of the samples, ranging from 4 to 79 μg/l.

Vanadium was detected twice and cobalt three times. Seven occurrences of nickel were reported, plus nine each for silver and arsenic. The number of positive occurrences, the frequency of detection and the ranges of the observed values in the Columbia River are shown in the following table.

Except for an increase in the zinc mean concentration at Pasco, there was no noticeable increase in metals below the Hanford Reactor.

In general, excellent detection limits were achieved in the Columbia River samples because total dissolved solids were low.

COLUMBIA RIVER

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	68	98.6	4	239	29
Boron	65	94.2	5	66	21
Iron	53	76.8	2	155	28
Manganese	37	53.6	0.5	8.1	2.5
Copper	67	97.1	1	28	8.7
Barium	69	100	3	61	30
Strontium	69	100	35	122	62
Molybdenum	27	39.1	2	66	19
Aluminum	27	39.1	10	57	24
Chromium	40	58.0	1	22	6
Lead	24	34.8	4	79	17

COLUMBIA RIVER AT NORTHPORT, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	100	14	40	26
Boron	7	87.5	6	19	10
Iron	7	87.5	4	155	29
Manganese	5	62.5	0.6	2.8	1.5
Copper	7	87.5	3	7	4
Barium	8	100	18	61	35
Strontium	8	100	36	67	52
Arsenic	3	37.5	30	66	48
Aluminum	3	37.5	15	31	21

This is the uppermost station in the Columbia River mainstem. The station is approximately 14 miles below the U. S.-Canadian border and 734 miles above the mouth of the Columbia River. The Pend Oreille River which rises in the United States and enters Canada is confluent to the Columbia above this station. Samples are collected from Washington State Highway Number 22 bridge at Northport.

Cadmium, beryllium, nickel, cobalt and vanadium were never detected at this station. Two occurrences each of molybdenum (3 and 11 µg/l), silver (0.2 and 0.6 µg/l), lead (6 and 9 µg/l), and chromium (4 and 4 µg/l) were recorded in addition to those elements listed above.

COLUMBIA RIVER AT WENATCHEE, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	11	100	7	48	18
Boron	11	100	6	54	15
Iron	9	81.8	2	100	27
Manganese	5	45.5	0.5	4.5	2.1
Copper	11	100	2	13	5
Barium	11	100	7	50	27
Strontium	11	100	43	108	59
Arsenic	3	27.3	23	65	46
Molybdenum	4	36.4	5	23	14
Lead	5	45.5	5	24	13
Chromium	4	36.4	3	22	8

This station is located at the plant intake of the Wenatchee works of the Aluminum Company of America, some 70 miles upstream from the Hanford Atomic Works. Wanatchee and East Wenatchee discharge wastes to the Columbia River about 12 miles upstream. Other industries in the area include irrigated agriculture, ore smelting and meat processing.

Grand Coulee Dam and Franklin D. Roosevelt Lake are about halfway between Wenatchee and the next sampling station at Northport, Washington, some 275 miles upstream. The Spokane River is confluent to the Columbia in Franklin D. Roosevelt Lake.

While zinc, boron, copper, barium and strontium were observed in all samples, cadmium, beryllium and vanadium were never detected. Aluminum at 23 and 27 µg/l, silver at 0.2 and 3.7 µg/l, nickel at 5 and 13 µg/l and cobalt at 14 and 17 µg/l were also recorded.

COLUMBIA RIVER AT PASCO, WASHINGTON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	16	100	7	239	47
Boron	15	93.8	5	28	12
Iron	7	43.8	2	146	33
Manganese	8	50.0	0.8	4.5	2.2
Copper	16	100	3	28	9
Barium	16	100	24	56	33
Strontium	16	100	43	94	58
Molybdenum	6	37.5	5	17	11
Aluminum	6	37.5	13	44	22
Lead	4	25.0	6	29	15
Chromium	11	68.8	3	21	8

The Pasco station is located above the mouth of the Snake River and below the mouth of the Yakima River. Samples are collected at the municipal water plant intake.

The Hanford Atomic Energy Works is located approximately 60 river miles above this station and its industrial wastes, including reactor cooling waters, are discharged to the Columbia River. The communities of Richland, Pasco and Kennewick, Washington utilize the Columbia River below the Hanford Works as a source of community water supply.

Richland, Washington discharges treated wastes into the Yakima River near its confluence with the Columbia. This confluence point is approximately six miles upstream from the Pasco station. Wenatchee is approximately 130 river miles upstream from Pasco.

Cadmium, beryllium and cobalt were never detected at this station. Two occurrences each of arsenic (45 and 70 µg/l) and nickel (11 and 15 µg/l) were recorded, as were single silver (0.8 µg/l) and vanadium (18 µg/l) values. Except for an increase in the zinc mean concentration, the Hanford Reactor appeared to have little effect on the metals concentrations in Columbia River water.

COLUMBIA RIVER AT McNARY DAM, OREGON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	14	100	10	38	21
Boron	13	92.9	14	66	30
Iron	12	85.7	4	146	22
Manganese	8	57.1	0.7	8.1	3.6
Copper	13	92.9	1	26	15
Barium	14	100	23	38	31
Strontium	14	100	39	122	72
Molybdenum	6	42.9	4	64	28
Aluminum	5	35.7	11	29	18
Lead	4	28.6	4	30	15
Chromium	10	71.4	2	9	5

The McNary Dam station is located in the powerhouse at the dam and monitors the outflow from McNary Reservoir. There are no major communities on the Columbia River between McNary Dam and the next upstream surveillance station at Pasco, Washington, 37 miles distance. There is, however, a pulp mill in this reach. The principal economic activity in the area is wheat farming. A moderate amount of irrigation is practiced. The Snake River is confluent to the Columbia in the McNary Dam-Pasco reach of the river.

In addition to those elements tabulated, two occurrences of silver at 1.1 and 1.6 µg/l and one of arsenic at 108 µg/l were recorded. Cadmium, beryllium, nickel, cobalt and vanadium were never detected.

COLUMBIA RIVER AT BONNEVILLE, OREGON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	7	78	31
Boron	8	88.9	11	62	34
Iron	7	77.8	5	95	29
Manganese	5	55.6	0.9	3.3	2.0
Copper	9	100	4	14	7
Barium	9	100	26	48	32
Strontium	9	100	42	105	69
Molybdenum	3	33.3	4	66	25
Aluminum	5	55.6	16	38	28
Lead	7	77.8	11	79	27
Chromium	6	66.7	1	22	6

The Bonneville station is located approximately 145 river miles below McNary Dam in the Bonneville Dam powerhouse. The Columbia River is navigable at this point and above. Occasional pollution has resulted from oil leaks in barges carrying petroleum products. Hood River and the Dalles, Oregon and White Salmon, Washington are the three major upstream communities. All are within 40 miles of the sampling point and discharge their treated wastes to the mainstem. There are lumber mills at Cascade Locks and Stevenson, Washington four miles upstream. The Columbia River in this area is extensively used for power production and recreation.

Cadmium, beryllium, silver, cobalt and vanadium were never detected at this station during the period of record. In addition to those elements summarized, arsenic at 53 µg/l and nickel at 7 µg/l were recorded on single occasions.

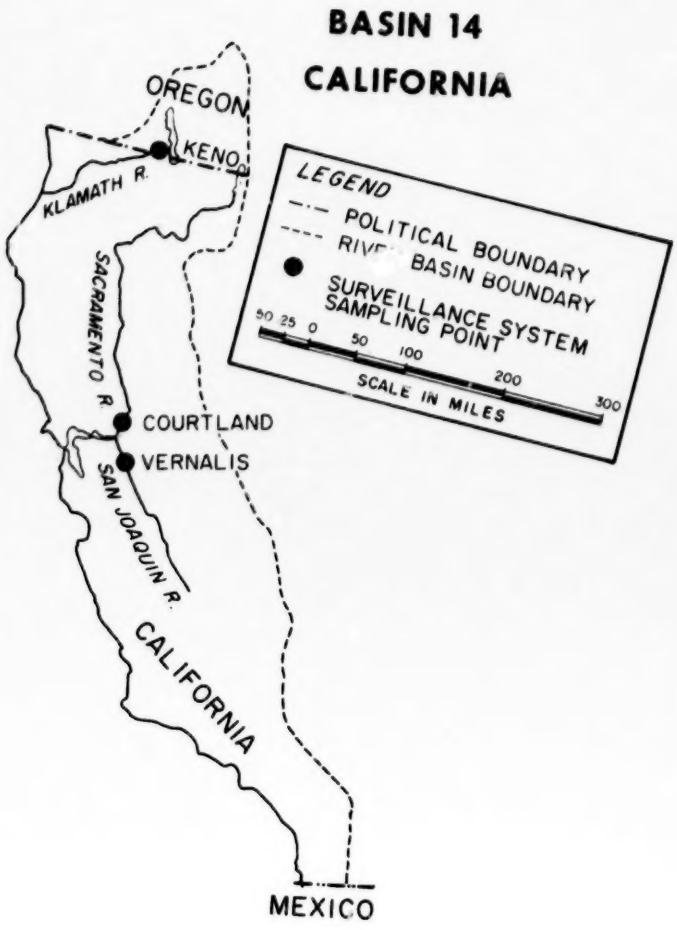
COLUMBIA RIVER AT CLATSKANIE, OREGON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, μg/l		
			Min.	Max.	Mean
Zinc	11	100	4	47	22
Boron	11	100	12	52	26
Iron	11	100	3	100	31
Manganese	6	54.5	0.6	5.0	2.7
Copper	11	100	3	19	9
Barium	11	100	3	41	23
Strontium	11	100	35	113	58
Molybdenum	6	54.5	2	54	20
Aluminum	6	54.5	10	57	28
Chromium	7	63.6	1	6	3

The Clatskanie station is the lower terminal water quality surveillance station on the Columbia River. Samples are collected at the wharf of Beaver Army Terminal, U. S. Army Transportation Supply and Maintenance Command, approximately 54 miles above the mouth of the river.

The Cowlitz and Williamette Rivers are confluent to the Columbia in the reach upstream from Clatskanie and below the next mainstem monitoring station at Bonneville, Oregon, 92 miles distant. Major upstream communities above the Clatskanie station are Portland, Oregon and Longview, Kelso and Vancouver, Washington. Grains and timber are the principal crops grown in the watershed of this reach, and pulp mills are the leading industrial activity, especially in the Kelso-Longview area.

Occurrences of arsenic (30 and 49 μg/l), silver (0.2 and 1.0 μg/l), nickel (2 and 8 μg/l), lead (4 and 15 μg/l), cobalt (1 μg/l) and vanadium (16 μg/l) were recorded. Cadmium and beryllium were the only two elements included in the routine program that were never detected.



APPENDIX N

BASIN 14 – CALIFORNIA

The California Basin covers some 111,000 square miles, of which about 4,500 are in Oregon. The Great Central Valley of California includes the Sacramento and San Juaquin Valleys, drained by rivers of the same names, with respective drainage areas of about 60,300 and 17,000 square miles. The Klamath River drains about 15,700 square miles in northern California and southern Oregon. A Water Quality Surveillance System station is located in each of these major basins. Flows throughout the Sacramento and San Joaquin Rivers reflect the operation of multipurpose dams and reservoirs. The upper reaches of the Klamath are also regulated.

Major industries include irrigated agriculture, food processing, petroleum production and refining, lumber, paper and allied products, electric power generation, aircraft and missile manufacturing and recreation.

Twenty-nine samples from this basin were analyzed. All contained barium at measurable levels, while strontium and boron were found in over 96%. Cadmium, arsenic, beryllium, silver and cobalt were never detected. The zinc and strontium mean values were below the national averages; the boron mean concentration in this basin exceeded the national mean by 40%. Other elements were either equal to or below national means.

SUMMARY OF TRACE ELEMENTS

BASIN 14 – CALIFORNIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	21	72.4	3	47	16
Cadmium	0	0	---	---	---
Arsenic	0	0	---	---	---
Boron	28	96.5	31	391	143
Phosphorus	18	62.1	10	189	83
Iron	27	93.1	3	227	46
Molybdenum	11	37.9	14	124	45
Manganese	13	44.8	0.5	7.8	2.8
Aluminum	5	17.2	10	232	63
Beryllium	0	0	---	---	---
Copper	20	69.0	3	45	12
Silver	0	0	---	---	---
Nickel	4	13.8	2	34	10
Cobalt	0	0	---	---	---
Lead	2	6.9	2	6	4
Chromium	6	20.7	2	45	15
Vanadium	2	6.9	21	40	30
Barium	29	100	6	163	42
Strontium	28	96.5	34	560	153

SAN JOAQUIN RIVER NEAR VERNALIS, CALIFORNIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	6	60	3	40	17
Boron	9	90	153	391	274
Iron	8	80	11	216	52
Manganese	3	30	2.3	5.0	3.3
Copper	4	40	6	32	14
Barium	10	100	37	163	94
Strontium	9	90	94	560	345

The Water Quality Surveillance System station near Vernalis provides data on water quality in the San Joaquin River just before it enters the tidal waters of the Sacramento-San Joaquin delta. Samples are collected from the San Joaquin city bridge. During the winter rainy season, and when large irrigation releases are being made from upstream reservoirs, the water is of excellent quality. During the low-flow months, flows in the lower reach of the San Joaquin River are made up entirely of irrigation return waters having excessive concentrations of salts.

In addition to those elements listed above, single occurrences of aluminum (10 µg/l), chromium (45 µg/l) and two of molybdenum (31 and 76 µg/l) were recorded. Cadmium, beryllium, silver, nickel and cobalt were never observed in positive concentrations. The boron, barium and strontium levels observed at this station were some of the highest within the California Basin.

SACRAMENTO RIVER AT GREEN'S LANDING ABOVE COURTLAND, CALIFORNIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	6	24	12
Boron	9	100	31	116	62
Iron	9	100	3	108	27
Manganese	4	44.4	0.5	2.0	1.5
Copper	8	88.9	3	13	8
Barium	9	100	14	38	21
Strontium	9	100	34	68	48
Molybdenum	3	33.3	14	18	16

This station collects water samples at the U. S. Bureau of Reclamation instrument house on the east bank of the Sacramento River at Green's Landing. Water levels and currents here are affected by semidiurnal tides. There are, however, no measurable ocean salts in the water. The water at Green's Landing is affected by organic loadings from the city of Sacramento's primary sewage treatment plant 17 miles upstream and, seasonally from the beet sugar plant six miles upstream. Inorganic loadings derive from upstream irrigation drainage.

In addition to those elements listed above aluminum was recorded at 28 µg/l in one sample. Two occurrences each of nickel (2 and 3 µg/l), lead (2 and 6 µg/l) and chromium (5 and 12 µg/l) were also observed. Cadmium, arsenic, beryllium, silver, cobalt and vanadium were never detected.

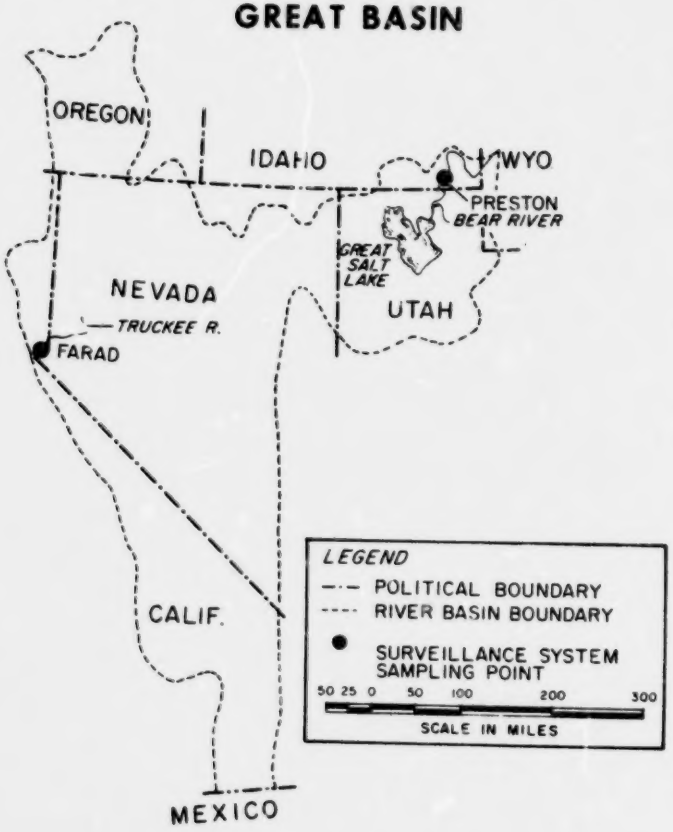
KLAMATH RIVER NEAR KENO, OREGON

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	70	8	47	21
Boron	10	100	56	158	98
Iron	10	100	7	227	57
Manganese	6	60	1.0	7.8	3.5
Copper	8	80	3	45	16
Barium	10	100	6	16	10
Strontium	10	100	42	129	76
Molybdenum	6	60	36	124	57
Aluminum	3	30	15	232	93
Chromium	3	30	2	26	11

The Klamath River near Keno drains a semi-arid interior plateau which includes some 200,000 irrigated acres. Samples are taken from the river below the John C. Boyle power plant, 220 miles above the mouth of the river. The Keno station is located below Klamath Lake near the California-Oregon State line.

In addition to 10 elements tabulated, the following were observed at lesser frequencies: nickel (2 and 34 µg/l), and vanadium (21 and 40 µg/l). Cadmium, arsenic, beryllium, silver, cobalt and lead were never detected.

BASIN 15
GREAT BASIN



APPENDIX O

BASIN 15 – GREAT BASIN

The Great Basin is the western desert region of the United States. The area has no surface outflow to the oceans. All of the streams originate in the surrounding mountains and terminate in closed lakes where equilibrium is maintained by inflow and evaporation. The Salton Sea lies within the Great Basin. This area was a sink prior to a breakthrough by the Colorado River which flooded the area in 1905-7. It now receives irrigation return flows.

Two water quality surveillance stations are maintained in the basin. These are on the Bear River at Preston, Idaho and on the Truckee River at Farad, California. The Bear River originates in the Wasatch Mountains of western Wyoming and flows into Idaho before bending southward into Utah where it discharges into Great Salt Lake near Brigham City, Utah. The Truckee River begins at Lake Tahoe on the eastern flank of the Sierra Nevada along the northeast edge of California. This is in a mountainous terrain. The lower portion of the Truckee drainage basin is arid.

Nineteen samples were analyzed within the time involved. Barium, boron and strontium were found in over 94% of all samples, while zinc, iron, molybdenum, manganese and copper were observed 58 to 74% of the time. Frequency of detection for aluminum, nickel, lead and chromium varied from 10 to 21%; cadmium, arsenic and silver were detected in only 5% of the samples. Beryllium, cobalt and vanadium were never detected within this basin. In general, the mean concentrations were below national levels.

SUMMARY OF TRACE ELEMENTS

BASIN 15 – GREAT BASIN

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	13	68.4	8	159	44
Cadmium	1	5.3	1	1	1
Arsenic	1	5.3	20	20	20
Boron	18	94.7	13	330	84
Phosphorus	5	26.3	8	104	37
Iron	14	73.7	3	557	70
Molybdenum	11	57.9	3	338	145
Manganese	11	57.9	0.4	23	7.8
Aluminum	3	15.8	2	27	15
Beryllium	0	0	---	---	---
Copper	14	73.7	2	70	12.6
Silver	1	5.3	0.3	0.3	0.3
Nickel	3	15.8	2	7	4
Cobalt	0	0	---	---	---
Lead	4	21.1	2	66	18
Chromium	2	10.5	3	6	4
Vanadium	0	0	---	---	---
Barium	18	94.7	10	113	41
Strontium	18	94.7	30	331	152

TRUCKEE RIVER, CALIFORNIA-NEVADA BORDER AT FARAD, CALIFORNIA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.9	8	57	32
Boron	9	100	13	44	22
Iron	8	88.9	3	58	14
Manganese	4	44.4	0.4	1.8	0.8
Copper	8	88.9	2	24	9
Barium	9	100	10	29	18
Strontium	9	100	30	100	56
Molybdenum	3	33.3	3	17	9
Aluminum	3	33.3	2	27	15
Nickel	3	33.3	2	7	4
Lead	3	33.3	2	4	2

The Farad station is located 21 miles below Lake Tahoe, above the point where the Truckee River enters Nevada. Samples are collected at the Farad power plant of the Sierra Pacific Electric Company. The primary upstream uses of water are domestic water supply, recreation, and hydroelectric power generation at Lake Tahoe. Downstream, the river supplies municipal water to Reno and Sparks, Nevada and irrigation water to the surrounding area before terminating in Pyramid Lake.

In addition to those elements tabulated, single occurrences of cadmium, arsenic and silver at 1, 20 and 0.3 µg/l were recorded. Chromium was detected on two occasions at 3 and 6 µg/l. Beryllium, cobalt and vanadium were never detected.

BEAR RIVER ABOVE PRESTON, IDAHO

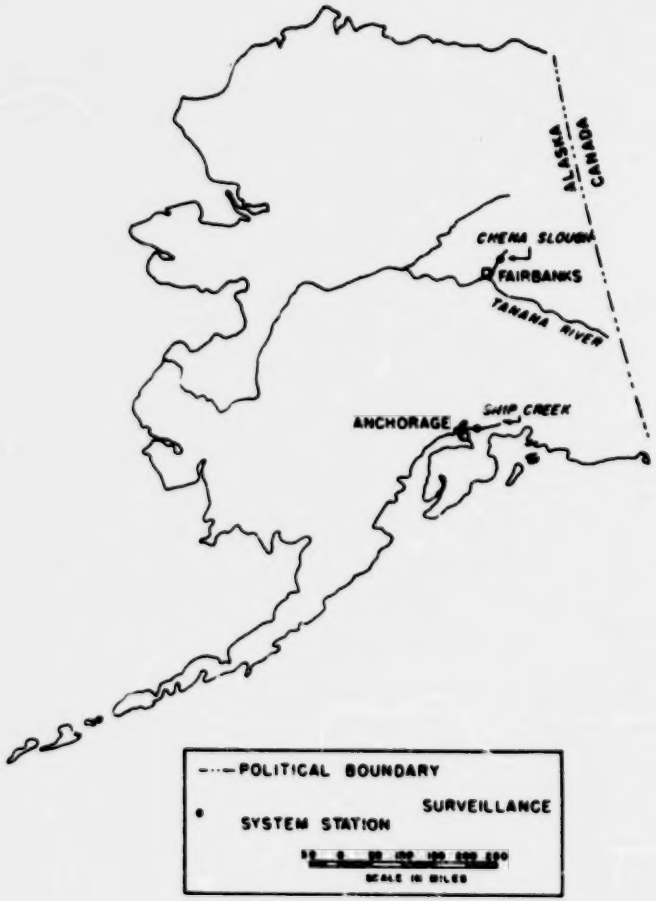
ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	5	50	19	159	63
Boron	9	90	97	330	147
Iron	6	60	10	557	145
Manganese	7	70	3.0	23	11.9
Copper	6	60	2	70	18
Barium	9	90	34	113	64
Strontium	9	90	202	331	249
Molybdenum	8	80	38	338	196

The Bear River surveillance station is nine miles upstream from the Idaho-Utah State line. Samples are collected at U.S. Highway 91 bridge, three miles northwest of Preston, Idaho. This stream eventually enters Great Salt Lake near Brigham City, Utah.

Approximately half of the upstream area is irrigated and dry land farming is practiced on the other half. Dairying, pasturage, and grain and sugar beet growing are the major activities. Pollution problems in the stream as a result of sugar beet refinery and municipal waste discharges are being corrected.

In addition to those elements listed above, lead was observed at 66 µg/l on one occasion. Cadmium, beryllium, silver, nickel, cobalt and vanadium were never detected.

BASIN 16
ALASKA



APPENDIX P

BASIN 16 – ALASKA

Alaska embraces over 586,000 square miles and has three climatic and hydrologic regions. The Water Quality Surveillance System station at Anchorage provides data on water quality in the southern region.

The Alaskan interior is bounded on the south by the Alaska Range with a maximum elevation of 20,300 feet at Mount McKinley, and on the north by the Brooks Range with elevations to 8,000 feet. Over 300,000 square miles of the interior drains into the Yukon River which heads within 25 miles of tidewater in southeastern Alaska and runs 2,300 miles to the Bering Sea. The Tanana River is a major tributary to the Yukon. The surveillance station at Fairbanks provides data on a tributary of the Tanana.

The western and northern region includes the Aleutian Islands, the Bering Sea coast, and the Arctic drainage basins. There are no surveillance system stations within this third region at present.

Eighteen samples were analyzed from the two stations within the time period here involved. Of the 19 elements routinely sought, three, i.e., cadmium, beryllium and cobalt, were never detected. Arsenic, silver, nickel, chromium and vanadium were found in less than 25% of the samples. Manganese was found in 60% of the samples; zinc, boron, iron, copper, barium and strontium were found in more than 83%. The mean values for most of these elements were below the national averages.

SUMMARY OF TRACE ELEMENTS

BASIN 16 – ALASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	15	83.3	5	88	28
Cadmium	0	0	---	---	---
Arsenic	3	16.7	32	36	34
Boron	18	100	10	120	28
Phosphorus	10	55.6	10	82	40
Iron	17	94.4	2	85	25
Molybdenum	5	27.8	2	34	17
Manganese	11	61.1	0.5	163	18
Aluminum	5	27.8	2	24	11
Beryllium	0	0	---	---	---
Copper	17	94.4	2	20	9
Silver	1	5.6	---	---	1.1
Nickel	2	11.1	3	7	5
Cobalt	0	0	---	---	---
Lead	7	38.9	2	35	12
Chromium	4	22.2	3	19	9
Vanadium	1	5.6	---	---	32
Barium	18	100	4	41	17
Strontium	18	100	14	341	81

SHIP CREEK AT ANCHORAGE, ALASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	8	88.8	5	59	23
Boron	9	100	10	40	24
Iron	8	88.8	2	44	15
Manganese	6	66.7	0.5	2.6	1.4
Copper	9	100	2	17	8
Barium	9	100	4	14	8
Strontium	9	100	24	165	79
Lead	6	66.7	2	35	13
Chromium	3	33.3	3	19	9
Arsenic	3	33.3	32	36	34

The Anchorage Surveillance System station is located in the Anchorage water treatment plant and obtains samples from Ship Creek Reservoir. This stream is the source of municipal water supply for Ft. Richardson and Elmendorf Air Force Base, and is used by Anchorage for part of its supply. The average diversion for this municipal use is 16 cubic feet per second.

Nickel at 3 and 7 µg/l, and single observations of molybdenum (2 µg/l), aluminum (2 µg/l) and silver (1.1 µg/l) were recorded. Cadmium, beryllium, cobalt and vanadium were never detected.

CHENA RIVER AT FAIRBANKS, ALASKA

ELEMENT	No. of Positive Occurrences	Frequency of Detection, %	Observed Values, µg/l		
			Min.	Max.	Mean
Zinc	7	77.8	16	88	32
Boron	9	100	10	120	32
Iron	9	100	8	85	34
Manganese	5	55.6	1.0	163	37
Copper	8	88.9	5	20	10
Barium	9	100	7	41	27
Strontium	9	100	14	341	84
Molybdenum	4	44.4	12	34	21
Aluminum	4	44.4	3	24	14

The Water Quality Surveillance System station at Fairbanks, Alaska is located at Fort Wainwright on the Chena River some 16 miles above the Chena River's confluence with the Tanana. The Chena River at the sampling point is occasionally referred to as Chena Slough. Municipal and industrial wastes associated with the city of Fairbanks are discharged to the Chena River downstream from the surveillance station.

In addition to those elements tabulated, single occurrences of lead at 11 µg/l, chromium at 10 µg/l and vanadium at 32 µg/l were recorded. Cadmium, arsenic, beryllium, silver, nickel and cobalt were never detected.